Virtual Reality in Earth Physics Learning: Research Trends through Bibliometric Analysis (2016-2020)

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Abstract. The use of technology in the education field is both exciting and challenging. Learning media such as Virtual Reality (VR) that applied futuristic strategy offered a virtual experience that can stimulate the cerebral cortex system could be an answer for the education needs in the revolution industry 4.0. This study aims to analyse the scientific trends of VR research in earth physics learning through bibliometric analysis from the Scopus database source period 2016 to 2020. A sampling of data was taken from the Scopus database using specific keywords for the period 2016-2020 on April 6, 2021. A total of 1,689 documents are gathered. It was found that there was a significant increase in the number of documents in 2020. Most of the documents were dominated by articles written in English. Indonesia also contributed a small amount of 14 documents out of the total documents gathered. It means there is still plenty of opportunities to research VR for education in Indonesia. The results highlight the optimism in using VR to teach earth physics by identified three clusters: model, student (sample), and literature. These clusters may help to recommend a new strategy for further VR research in the education field.

1. Introduction

Along with the rapid development of Science and Technology these day, technology affects many fields, including education. The evolution of technology used in learning has resulted in more and more demands to utilize and make innovations that are better and beneficial for education. Teachers in the millennial era are facing challenges in delivering subjects to the students. One of the innovations we can use in education is to determine a good learning strategy. The characteristic of a good learning strategy is that learning can involve students to bring about an activity that is following the learning objectives [1]. One of the learning strategies we can review from the consideration of teacher-student interaction proposed by Dalyono is a learning strategy through the media and interact with the media as "representatives" of the teacher, and used to draw up modules, computers, and other technologies [1]. A research by Purwono in 2014 showed that student learning outcomes increased after the teacher used audio-visual media or illustrations. This result was supported by an increase in scores on test results and in student understanding [2].

One example of rapid development science and technology in learning media is Virtual Reality. Virtual reality (VR) is a technology that allows users to interact in an environment that is artificial by a computer [3]. VR, in general, is widely used in the fields of education and training due to VR potentials in providing stimulating interactive activity and motivation [7]. Furthermore, VR offers an ideal manner to approach, study and remember new knowledge for

all those who prefer a visual, auditory or kinaesthetic learning style [8].We can use virtual reality to introduce practical knowledge in class without actually leaving the classroom and make the educational experience beneficial.

Benefiting from these developments, a virtual world can be created for public and professional to immerse themselves into an environment to experience a disaster or extreme weather event. Using VR with artificial realistic various natural disaster scenarios make it possible to learn, train, and also reduce the limitations and challenges of real-world learning [4]. The need for disaster management training increases over the next decade; mainly due to the effects of global warming; Moreover Indonesia is a country that highly prone to natural disasters. Therefore, institutions need to prepare for the worst disaster risks. Disaster risk reduction and emergency specialists can obtain an invaluable experience from VR environments in which different disaster scenarios could be simulated and the personnel could be trained to respond to critical situations with confidence [5]. Emergency preparedness virtual reality simulations can provide more varied schemes and help avoid the panic that could lead to accidents and deaths that should not have occurred [6].

Currently, there are many learning media based on VR technology like software and applications. However, there has been little effort to collect data on VR research in earth physics learning all over the map. This study presents trends in VR research in earth physics learning through a bibliometric analysis conducted to evaluate publications of VR research in earth physics from 2016 to 2020 based on the Scopus database.

To make VR more effective in education, it is crucial to know some far-reaching questions regarding VR research trends in earth physics learning from 2016 to 2020. Questions as follows:

1. How were the results of VR research publications in learning earth physics from 2016-2020?
2. To what extent did the distribution of VR research publications in earth physics learning in 2016-2020 based on the publication output, document sources, and language sources?
3. To what extent did the distribution of VR research publications in earth physics learning in 2016-2020 across countries in the world?
4. Who were the top authors for VR research in earth physics learning in 2016-2020 based on the number of publications and citations?
5. To what extent did the contribution of Indonesian researchers to VR research in learning earth physics in 2016-2020?
6. How did the visualization results of VR research trends in earth physics learning in 2016-2020?

2. Research Methods

This research uses the bibliometric analysis method. The bibliometric analysis provides a precise method for evaluating a paper's contribution to progress knowledge [9-11]. In this study, the data were obtained from the Scopus database. Scopus was chosen because is the world's largest academic database with citations providing abstracts from various scientific and research literature that have been reviewed [12]. So that Scopus database is effective for visualizing, tracking, and analysing a study. Search data on Scopus using the keyword search term: virtual AND reality AND earth AND science AND (LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016)) AND (LIMIT-TO (SUBJAREA , "SOCI")). The gathered data is taken from the Scopus database using the keywords from 2016-2020 on April 6, 2021. A total of 1,689 publication documents have been identified. Microsoft Excel and VoSViewer were used to analyse the data. Investigation carried out to analyse research trends which include the characteristics of publications, source documents, languages, countries, affiliations, top authors, top citations, Indonesia's contribution to research, and VR research publication trends in earth physics learning from 2016 to 2020.

3. Results and Discussion

There are 1,689 publication documents related to VR in earth physics learning in Scopus database.

3.1. Results of publications, types of documents, number of publications by language and country

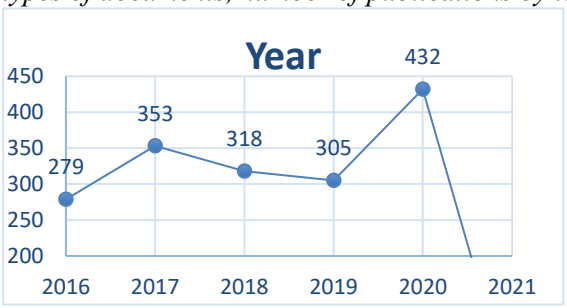


Figure 1. Number of documents per year 2016-2020

In Figure 1, a graph of the number of documents per year 2016-2020 is presented. There is no significant difference in 2016-2019. In 2020, there was a significant increase in the number of documents, from 305 documents in 2019 to 432 documents in 2020. Which shows that there is an increase of 127 documents. It could be said to be a big increase. This increased in number also indicates the increasingly widespread use of VR in learning, particularly earth physics. Virtual Reality (VR) has been used as education tools for some time in schools and colleges in the recent years. The main reasons because its' advantages to support high interactivity and the abilities to present a virtual environment that resembles the real world [13]. Many potential benefits of using VR in education and training are as follows [16-20]: Education which is not possible in reality, will be possible in virtual reality; Virtual game-based experience increases students' motivation; Collaboration in virtual reality classroom fosters social integration of learners; Learning is achieved by direct interaction, not by mouse clicks. For example earth science learning in SMALLab to aid learning about geologic evolution [14]. The development of VR growing fast in 2012 thanks to the invention of virtual reality goggles Oculus Rift by Palmer Luckey [15]. This invention makes it easier to use VR in people's life. Virtual reality is appreciated more and more by the scientific community.

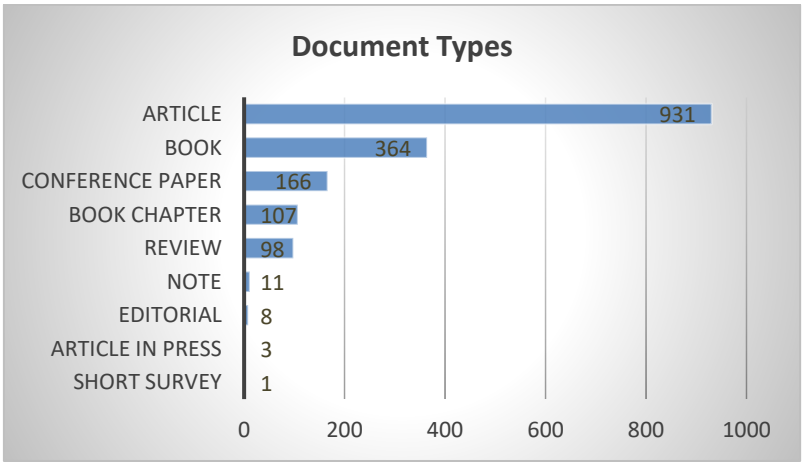


Figure 2. Number of publications for each type of document

Based on Figure 2, articles are the most common type of publication, namely 931 articles. Followed by books, conference papers, book chapters, and reviews. Some selected paper showed that a relevant

number of them refers to university or pre-university learning, which VR appears to be widely used as adult training. Very limited use of VR with younger children is probably because they are still growing and 3D vision, as well as hand-eye coordination and balance are still under development [7].

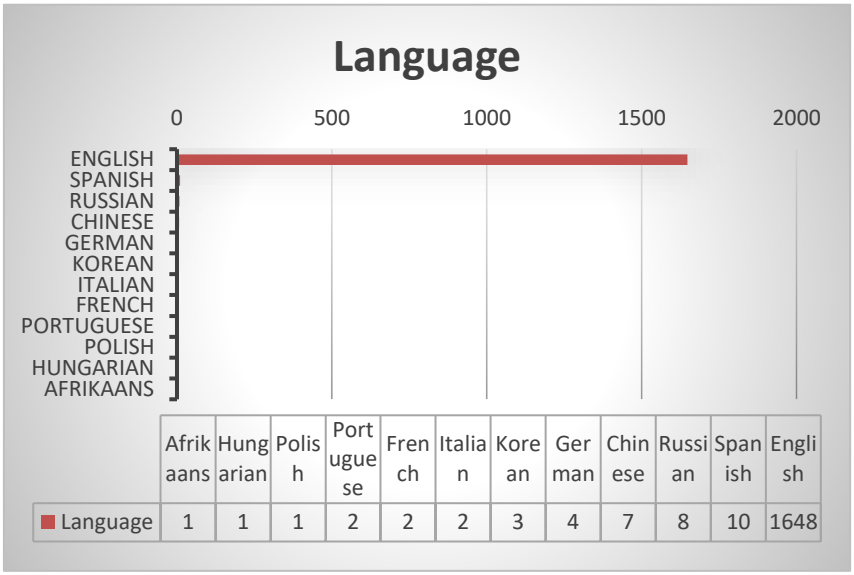


Figure 3. Distribution of documents based on language

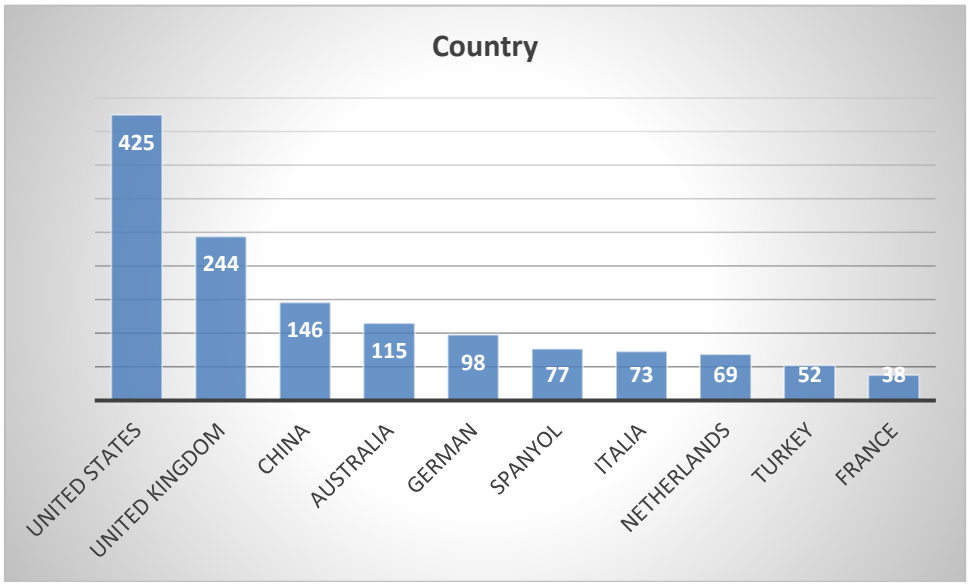


Figure 4. Distribution of top 10 countries that publish the most document

Meanwhile, based on language (Figure 3) and country (Figure 4), out of a total of 1,689 documents, its' 1,648 is in English. This number shows that 97.6 % of the document is in English, as known as the International Language. Then followed by Spanish, Russian, and Mandarin. There are a total of 12 languages in number of documents found. Most papers have been published in the United States, and a relevant number in United Kingdom. For about a quarter of the documents, namely 425 documents, then followed by United Kingdom 244 documents and China 146 documents. Seems like there is a significant difference from the United States to the United Kingdom and so on. It means that the United Stated showed a relevant interest in Virtual Reality in earth physics learning research.

United States, United Kingdom, and China is substantially ahead of other countries in terms of both incorporating science and technology into education [21].

3.2. Top author based on the most publications and citation on VR research in Earth physics learning in 2016-2020

Table 1. Top 10 authors of VR research in Earth physics learning based on the number of publication

Author	Documents	Total link strength
Li, w.	12	22
Li, y.	12	12
Zhang, h.	9	16
Herman, l.	9	10
Chen, y.	9	3
Zhu, j.	8	26
Zhang, y.	8	15
Wang, s.	8	4
Çöltekin, a	8	3
Hu, y.	7	25

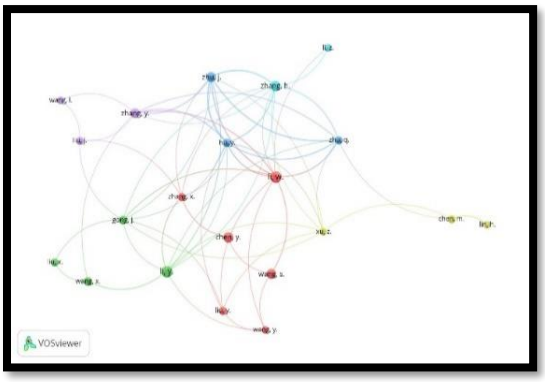


Figure 5. Distribution of Top 10 authors of VR research in earth physics learning based in number of publications

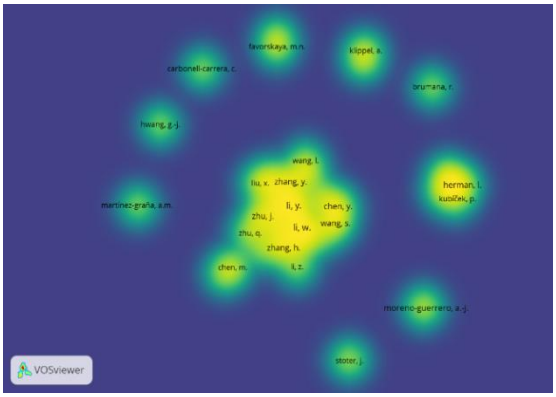


Figure 6. Density visualization of Top 10 authors of VR research in earth physics learning based on number of publications

In Figure 6 and Table 1, the results of the bibliometric analysis of the top authors are presented using VoSViewer. Each author is also grouped by the cluster. Through *density visualization* (Figure 6) it can be seen that the brightest or dominant is a group of researchers from China. Among the ten authors the most productive ones are Cluster 1 Li, W and Cluster 2 Li, Y which have both been published 12 documents. While in Table 2, the top 5 authors are presented based on the number of citations. A total of 215 citations is articles from Holbraad M., Pedersen MA from Cambridge University.

Table 2. Top 5 authors by number of citations per 2016-2020

Author (s)	Year	Citations	Publisher
Holbraad M., Pedersen M.A.	2017	215	Cambridge University Press
Ceschin F., Gaziulusoy I.	2016	184	Elsevier Ltd
Ash J., Kitchin R., Leszczynski A.	2018	150	SAGE Publications Ltd
Ibáñez M.-B., Delgado-Kloos C.	2018	148	Elsevier Ltd
Verburg P.H., Dearing J.A., Dyke J.G., Leeuw S.V.D., Seitzinger S., Steffen W., Syvitski J.	2016	147	Elsevier Ltd

3.3. Contribution of Indonesian Researchers to VR research in learning earth physics for the 2016-2020

There are 14 publication documents from Indonesia, consisting of articles, conference papers, and notes, 84 % of which are articles (Figure 7). In Table 3 presented that there are 14 institutions from each author and *co-author*. UPI, Unnes, and UGM is ranked first with two documents each, while the other nine institutions contributed only one document. This small amount of documents means that there is still plenty of opportunities to research VR for education in Indonesia. The main possible reason is that as educators with non-technical backgrounds, the process of building a VR system for educational application has been extremely challenging [22]. In order for VR to become mainstream in Indonesia, educators need to be able to get out of comfort zone and create new innovations for education in Indonesia, suppose making a VR content or application.

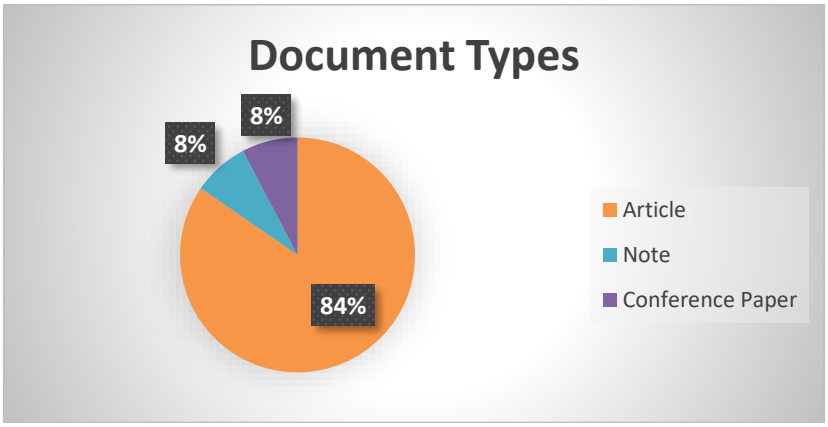


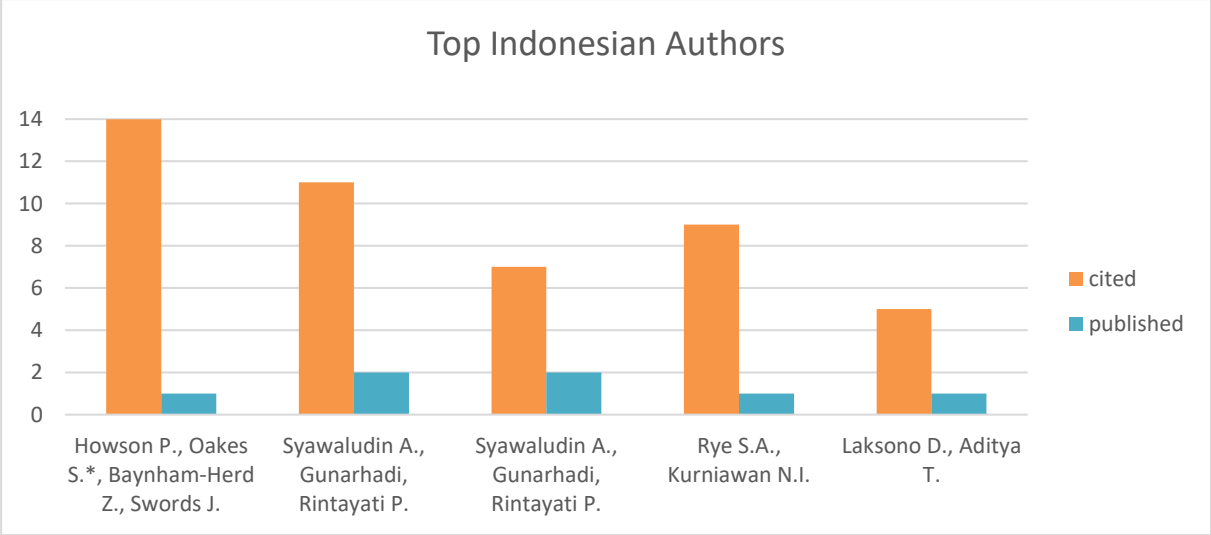
Figure 7. Percentage of publications by Indonesian researchers based on documents type

Table 3. Number of documents in each institution in Indonesia

No.	Affiliations	Number of document
1.	Universitas Pendidikan Indonesia	2
2.	Universitas Sebelas Maret	2
3.	Universitas Gadjah Mada	2
4.	Bandung Institute of Technology	1
5.	Universitas Indonesia	1
6.	Universitas Sultan Ageng Tirtayasa	1
7.	Surabaya State University	1
8.	Universitas Pasundan	1
9.	Universitas Muhamadiyah Sidoarjo	1

10.	Universitas Swadaya Gunung Jati	1
11.	Universitas Pancasila	1
12.	Ahmad Dahlan University	1
13.	Institute of Science and Technology AKPRIND	1
14.	Naval College of Technology	1

Indonesian top writers (Figure 8) based on the number of documents are Syawaludin A., Gunarhadi, Rintayati P., from Universitas Sebelas Maret, who has published 2 documents in 2019 in 2 different journals. The first article has been cited 7 times and the second article has been cited 11 times. Meanwhile, based on the number of citations (Figure 8) is Oakes S. with a total of 14 citations. Research conducted by Oakes S. conducted with researchers from the UK (United Kingdom). From the twelve publication sources (Table 4), the Indonesian Science Education Journal from Universitas Sebelas Maret ranked first with a total of 3 documents. Two of them in 2020 and another in 2019 by Syawaludin A. from Sebelas Maret University.



**From Indonesia*

Figure 8. Top Indonesian authors

Table 4. Number of documents from Indonesia based on the Journal or Conference

No.	Journal or Conference	Number of Document
1	Jurnal Pendidikan IPA Indonesia	3
2	International Journal of Geoinformatics	1
3	Journal of Design and Built Environment	1
4	International Journal of Emerging Technologies in Learning	1
5	Journal of Security and Sustainability Issues	1
6	International Journal of Instruction	1
7	International Journal of Scientific and Technology Research	1
8	ISPRS International Journal of Geo-Information	1
9	Geoforum	1
10	International Journal of Architectonic, Spatial, and Environmental Design	1

11	Political Geography	1
12	Proceedings - 2015 International Conference on Science in Information Technology: Big Data Spectrum for Future Information Economy, ICSITech 2015	1

3.4. Visualization of Research Trends based on VoSViewer Software

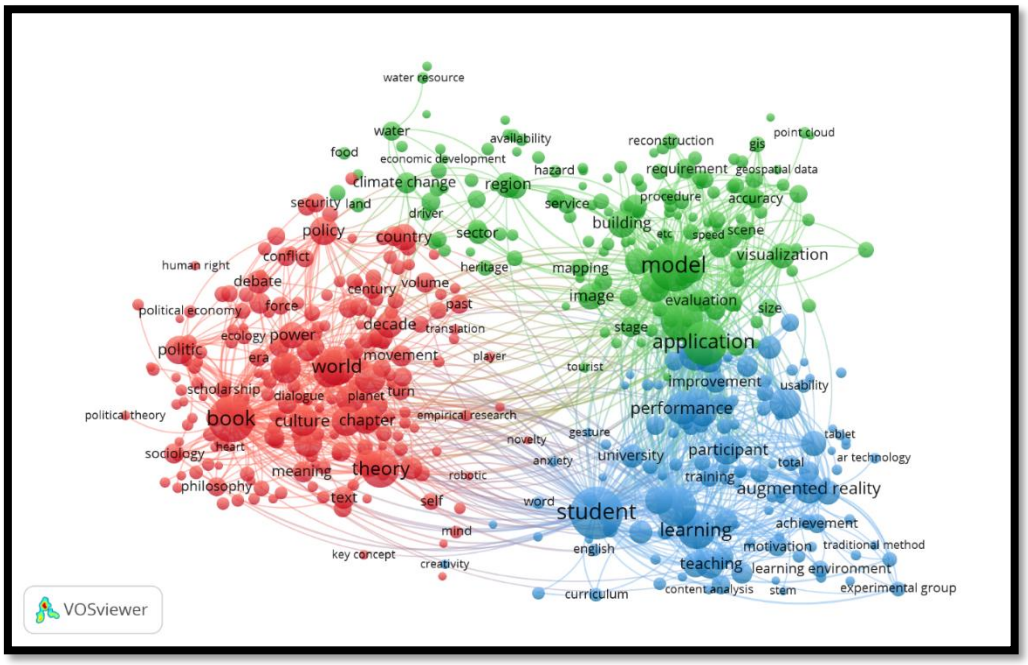


Figure 9. Network visualization

All 1,689 documents related to VR research in earth physics learning at Scopus database was visualized with the help of the VoSViewer software. This method is useful for finding research trends and research novelty. The colored circle shows the item or keyword. Total of 485 keywords appear on the title and abstract. The size of the circle also indicates how often related research topic is done. If the size of the circle is getting bigger and the keyword appeared more frequently. The results show that there are several important clusters or linkages with model, students (sample), and book (library review). From the mapping results, there are 3 clusters (red, blue, and green) that show a relationship between one topic and other topics (Figure 9). Cluster 1 is shown in red, cluster 2 is green, and cluster 3 is blue. The focus of this research is the keyword Virtual Reality which is in cluster 3, appears 138 (occurrence), and quite a lot of linked items (Links: 343 and total link strength: 1368) (Figure 10).

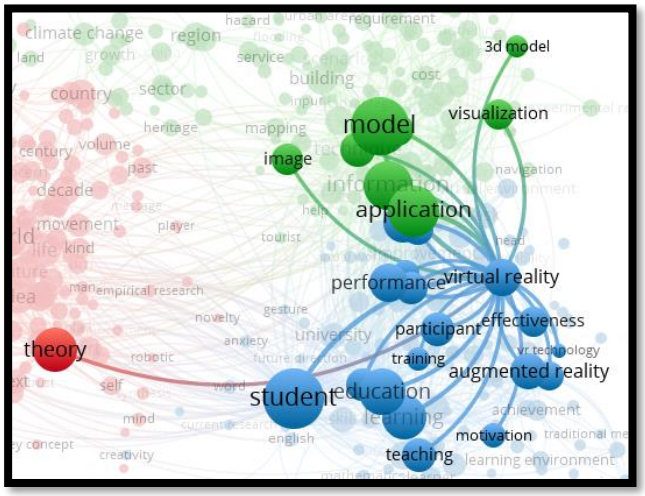


Figure 10. Virtual reality network visualization

The keyword VR is closely related to the model, student, and theory. From the literature review, VR is generally widely used in the field of education and training because of its' potential to stimulate interactivity and motivation [7]. Therefore, there is a lot of VR research in the field of education with a sample of students. Talking about the use of VR in education, this is one of the strategies learning through media. The VR media used must be the result of research the development of VR-based media, which are mostly models of a theory. Because theory is a kind of rational abstract thinking about a phenomenon, or the result of thought, which means that its form is still abstract, therefore it is necessary to build a model in learning. For example, develop VR on materials relativity by Sumardani [23]. Teaching the special theory of relativity is challenging. It's difficult because this topic has never happened in real experience, and there hasn't been technology launched at the speed of light. To understand this theory, VR has the potential to visualize the true concept of relativity by presenting artificial environment to students (modelling).

Figure 11. The relationship between VR and and disaster

Figure 12. The relationship between VR earthquake

In order to know the novelties related to disasters and earthquakes in VR research on earth physics learning, the specific connections between variables were examined, the results have several findings Figures 11 and 12. These figures show that research related to disasters and earthquakes has not much done. This is indicated by the absence of a *link* in the image. However, 'disaster' keyword entered in network visualization in cluster 2, appeared 32 (occurrence*)*, and not many related items (Links: 196 and total link strength: 360). Then the keyword 'earthquake' is included in the network

visualization in cluster 2, appeared 13 (occurrence*)*, and not many related items (Links: 111 and total link strength: 173). Disaster risk reduction or education about earthquake or other natural disasters is very much needed (in some in some disaster-prone areas). Some problems of disaster education can be overcome with VR. Making a virtual natural disaster situation make it possible to learn, train, and also reduce the limitations and challenges of actual learning in class [4]. These situations include responding to mass casualties, dealing with natural disaster. Simulation-based training can be a valuable training modality in these situations, as it allows opportunities to practice and prepare for high-risk and often low-frequency events [24].

4. Conclusion

Bibliometric analysis on VR research in learning earth physics in 2016-2020 from the Scopus database has been carried out with results 1,689 publication document gathered. There was no significant difference during the first three years until 2020, when there is a significant increase in the number of documents. Most of the collected document are dominated by articles written in English from The United States of America. Authors Li, W and Li, Y have published the most, both published 12 documents. Meanwhile, the most cited articles is by author Holbraad M., Pedersen MA which cited 215 times. Indonesia also contributed a small amount of 14 documents out of the total documents gathered. It means there is still plenty of opportunities to research VR for education in Indonesia. The results highlight the optimism in using VR to teach earth physics by identified three clusters: model, student (sample), and literature. These clusters may help to recommend a new strategy for further VR research in the education field.

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