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One Decade Trends of Virtual Reality Publication in Physics (2012-2021)

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Abstract: This bibliometric Study aims to scope the trend of virtual reality (VR) publications in physics for 2012-2021 with Scopus and Google Scolar as literature sources. The results of bibliometric study show that the trend in VR research increased annually. In one decade, 68 published papers indicated the growth of VR research in physics. About 60% of papers were published in conference proceedings. The mapping of papers' origin identified the United States as the top country contributing to VR research publications and the leading publishers of the Institute of Electrical and Electronics Engineers Inc. and Springer. VR research has been growing well in developed countries. Meanwhile, developing countries seem to follow the trend that can be seen from the author's origins. “Virtual reality, physics, application, study, and use” are often used as keywords by the authors. The top three authors were identified from Kazakhstan, namely Y. Daineko, M. Ipalakova, and D. Tsoy. Indonesia also contributed with two publications from Jurnal Penelitian Pendidikan Fisika (JPPF) and Jurnal Pendidikan Indonesia (JPI). Even though this study has limitations in exploring the trend based on specific keywords, periods, and sources, these results are valued as a stepping stone in framing VR research in the future.

Keywords: virtual reality, physics, bibliometrics, literature studies, VOSviewer

Abstrak: *: Studi bibliometrik ini bertujuan untuk mengetahui tren publikasi Virtual Reality (VR) dalam fisika pada rentang tahun 2012-2021 dengan menggunakan sumber literatur Scopus dan Google Scolar. Hasil studi bibliometrik menunjukkan bahwa tren penelitian VR meningkat setiap tahunnya. Dalam satu dekade, terdapat 68 publikasi yang menunjukkan pertumbuhan penelitian VR dalam fisika. Sekitar 60% publikasi diterbitkan dalam prosiding konferensi. Pemetaan asal publikasi mengidentifikasi Amerika Serikat sebagai negara teratas yang berkontribusi pada publikasi penelitian VR, sementara untuk penerbit teratas berasal dari Institute of Electrical and Electronics Engineers Inc. dan Springer. Penelitian VR telah berkembang dengan baik di negara-negara maju. Sementara itu, negara-negara berkembang nampaknya mengikuti tren yang dapat dilihat dari asal-usul penulisnya. “Virtual reality, physics, application, study, dan use” sering dijadikan kata kunci oleh penulis. Tiga penulis teratas diidentifikasi dari Kazakhstan, yaitu Y. Daineko, M. Ipalakova, dan D. Tsoy. Indonesia juga berkontribusi dengan dua publikasi dari Jurnal Penelitian Pendidikan Fisika (JPPF) dan Jurnal Pendidikan Indonesia (JPI). Meskipun penelitian ini memiliki keterbatasan dalam mengeksplorasi tren berdasarkan kata kunci, periode, dan sumber tertentu, hasil ini dinilai sebagai batu loncatan dalam membingkai penelitian VR di masa mendatang.*

Kata kunci: *realitas virtual, fisika, bibliometrik, studi literatur.*

▪ INTRODUCTION

Science and technology continue to evolve each time rapidly, followed by the urge to master new skills for adapting technology in all sectors, including education. Teachers should overcome challenges in preparing a generation that is adaptive to the new modern technology era. Skills in utilizing technology in everyday life have become a must for students in the 21st century. Nowadays, digital learners need technological

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orientation learning, one of which is applying technology-based media in the learning process (Abdussalam, Sulthoni, & Munzil, 2018). Technology in learning possibly acts as media that can interpret abstract concepts in materials to be more easily understood by students (Rahayu, Iskandar, & Abidin, 2022). Learning media has various forms and innovations, including learning media that combine audio and visuals, such as Virtual Reality (VR). VR technology presents a world of images representing the real world to support students' understanding of materials, concepts, and thinking patterns. The principle of VR technology is to shape information from the physical environment into the virtual world for VR users (Huang et al., 2019).

In the virtual world, students have a learning experience with a sense of presence being part of the virtual environment (Dergham & Gilanyi, 2019). Those use of VR in education can make learning memorable through interactions in a virtual world that utilize students' emotional core in new and interesting ways (Tomchinskaya, et al., 2018; Zulherman et al., 2021). VR technology can be the perfect catalyst to convey complex physics concepts through engaging learning (Budi et al., 2021). The implementation of VR technology in education is expected to improve the conventional teaching method, which is less interactive and lacks engaging media that further instils a sense in students (Purwati et al., 2020). VR technology has potentially increased the effectiveness and motivation of students' learning, thus allowing them to have an immersive learning experience (Chang et al., 2020).

In this regard, the potential of VR technology raises attention and research interest in developing VR in various research areas, including Physics. In physics learning, VR technology helps to explain the matter in the classroom and carry out practicums or experiments in three dimensions (Budi et al., 2021). For example, research conducted by Sukirman et al. presented a virtual world through VR to simulate disaster mitigation (Sukirman, Reza, & Sujalwo, 2019). Disaster mitigation is a complex concept requiring contextual learning situations to better understand risk in prone disaster environments. Research conducted by O'Connor et al. uses the virtual world to explain atomistic physics from the micro-scale in classroom meetings (O'Connor et al., 2018). This research explains that VR allows a more accurate representation of tiny things, making it easier to explain atomic physics concepts in class. This demonstrates that visualizations through VR can affect people's understanding of material concepts. Those should be a potential for conducting further research.

Through literature studies, researchers want to discover the potential of VR research, especially in the field of physics. In this study, researchers use bibliometric analysis. The study looked for literature on the application of virtual reality in physics. The articles are analyzed by software and then mapped using the bibliometric approach. The bibliometric analysis offered a precise approach to assess a paper's contribution to knowledge growth (Suprapto et al., 2021). It has been common practice to examine trends using bibliometric indicators, which include study areas, document sources, publishing outputs, language sources, distribution of nations and institutions, number of citations, top authors, and author keywords (Su et al., 2020; Suprapto et al., 2021). By mapping knowledge domains, author contributions and collaboration have been investigated (Tan et al., 2021). Besides that, the study may be conducted to research gaps and facilitate clear and precise information that will improve the development of VR research, including physics (Tran et al., 2019). The following study examines VR

research trends in physics in the last ten years (2012-2021). Previous research has conducted a study review of VR-related research in physics learning (Budi et al., 2021). In line with that, we use bibliometric analysis to uncover the topography of VR research in physics and complement the previous study results. This study was obtained to frame the current research trend and give future recommendations for other researchers to develop the research topic. The study includes the following questions:

1. What are the results of VR research publications in physics from 2012-2021?
2. How do all countries distribute VR research in Physics publications from 2012-2021?
3. How does the distribution of VR research publications in physics in 2012-2021 based on the type of document, publication sources, and publishers?
4. Who is the top author for VR research in physics in the range of 2012-2021 based on the number of publications and citations?
5. How does the visualization of keyword linkages often used by authors for VR research in the field of physics in 2012-2021?
6. How did Indonesian researchers contribute to the publication of VR research in physics from 2012-2021?

▪ METHOD

Research Design and Procedures

This study applied a literature study statistical analysis to map the distribution of publications on a particular topic to understand better the desired topic (Suprapto et al., 2021). This study retrieved data from two databases, namely Scopus and Google Scholar. The researchers searched the publications in the database by using three keywords, namely "virtual", "reality", and "physics". The search results are limited to publications of the last ten years (2012-2021). The search results were filtered to remove duplication, inaccessible thesis/dissertation, and unopened articles. Then, the final search results will be processed by Excel and VOSviewer to find the answers to the study's questions. The overall study method is mapped in the following flow chart.ve the development of VR research, including physics (Tran et al., 2019).

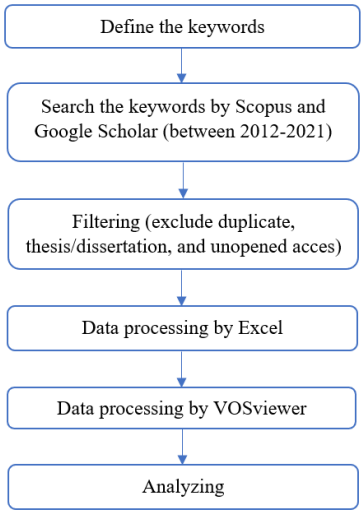


Figure 1. Flow chart of data retrieval and processing

Research Subjects

The result from Scopus showed that 44 documents related to the keywords. Meanwhile, the search result from Google Scholar showed 129.000 documents. The documents were then reduced to 97 by applying restrictions on search based on the titles; any titles do not contain the three keywords were removed. The next step is screening the documents to exclude duplication, any theses or dissertations that were not publicly accessible, and links that could not be opened, resulting in 24 documents. In total, 68 documents from both databases matched this study's criteria.

Instrument

In this study, the researcher is an instrument, which means that the researchers themselves interpret the meaning and find the values of this study. Researchers are also planners, executors, data collection, analysis, data interpreters and, in the end, a pioneer of research results (Moleong, 2018).

Data Analysis

Those search results data were exported in CSV (Comma Separated Values) and RIS (Research Information Systems) formats. For Google Scholar, the results were manually noted data related to the title, publication source, year of publication, and country. CSV formatted data and data recorded manually from Google Scholar searches are further processed using Excel to obtain analyses not listed on VOSviewer. The analysis covers the publication trends of selected topics year after year, document type, countries with the most publications, journals with the most publications, and publishers with the most publications. RIS formatted data will be processed and mapped using the VOSviewer program to see the bibliometric mapping. This mapping applies a co-occurrence analysis that reveals a topic statistically by looking at the relationship between keywords; the more often there is a pair between two keywords, the closer the relationship between the two (Fryda, Ayudha, & Setyarsih, 2021). Mapping is done with two types of mapping. The first mapping is done based on the title and abstract of the article data to see keywords or terms that are interrelated from the article data obtained (Al-Ashmori, Othman, & Rahmawati, 2020). The second mapping is done based on the author's name to see how many authors publish articles on virtual reality research in physics and how connected among authors on the same topic.

Because the number of documents obtained is relatively small, this study applied two restrictions. The first restriction is aimed at keywords with five appearances as a minimum number of occurrences, while the second restriction with ten appearances (VOSviewer recommendations). The mapping of the authors is conducted three times, with the appearance of the author's name limited to a minimum of one document, a minimum of one document with further filtering, and a minimum of four documents.

▪ RESULT AND DISSCUSSION

Research Trends

The number of publications on Virtual Reality (VR) in physics from 2012 to 2021 based on data obtained from Scopus and Google Scholar (68 documents) presented in Figure 2. Publication data is limited to 2012-2021, so relevant and up-to-date scientific publication documents are obtained. Based on the graph above, the number of publications on VR in physics tends to increase annually, especially over the last five

years (2017-2021). It means that research on VR in physics is increasingly being done and published by researchers from year to year so that it can be categorized as the latest research trend.

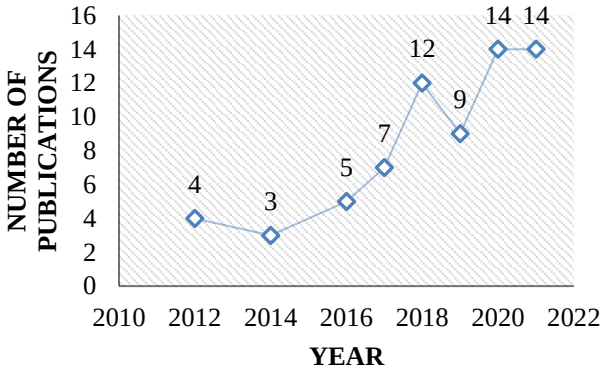


Figure 2. Trends on virtual reality (VR) research publications in physics (2012-2021)

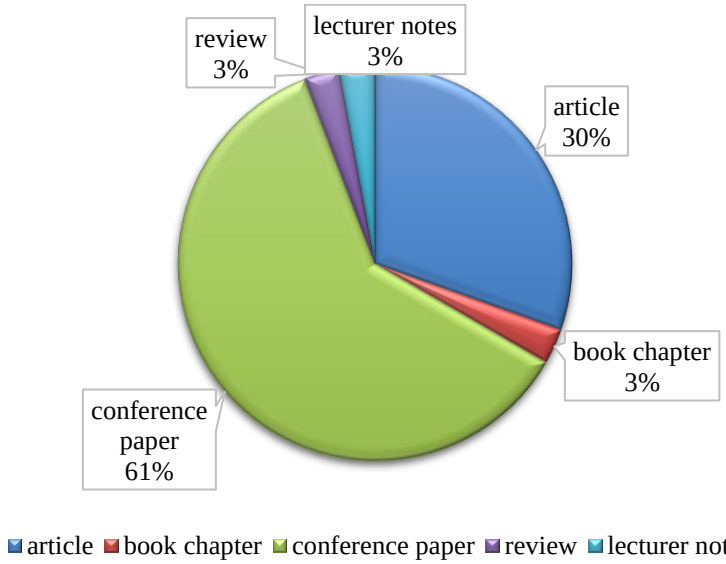


Figure 3. Distribution of virtual reality (VR) publication in physics (2012-2021)

Figure 3 shows the dominance of the type of document being published. It can be seen that more than half of publications related to VR in physics are conducted through conferences. This can be seen from the document type with the most publications, 61% in the form of conference papers. Meanwhile, the remaining 30% are in the form of articles uploaded in scientific journals, 3% in the form of a chapter in books, 3% in the form of lecture notes, and 3% in the form of reviews.

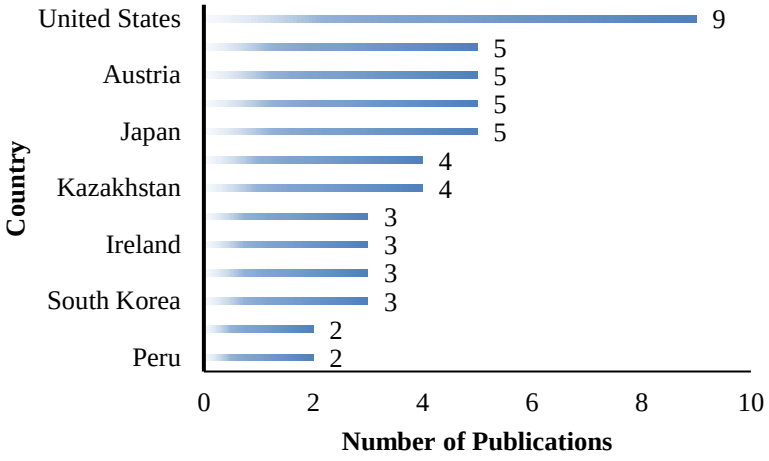


Figure 4. Top countries on virtual reality (VR) publication in physics (2012-2021)

Figure 4 shows each country's contribution to the publication of research related to VR in the field of physics. The United States ranks first with nine publications out of the total, marking it as the country with the most contributions related to VR in physics. Below that, Australia, Austria, China, and Japan took second place with five publications. Germany and Kazakhstan are in third place with four publications. Cyprus, Ireland, the United Kingdom, and South Korea are in fourth place with three publications. Indonesia and Peru are in fifth place with two publications. Meanwhile, other countries such as Portugal, Brazil, Serbia, Oman, Netherland, Ecuador, Pakistan, Greece, Poland, Finland, Italy, Arabia, and Malaysia have contributed with one publication.

Based on these data, research on VR in physics is still dominated by countries from America and Europe. Countries in East Asia such as Japan, South Korea, and China seem to show their contributions even though they are not dominant. However, developed countries are still minimally visible, indicating a lack of publications on VR research in physics. Meanwhile, Indonesia has contributed to VR research in physics with two publications, showing that researchers in Indonesia are interested in publishing related to VR in physics.

Table 1. Top sources on virtual reality (VR) publication in physics (2012-2021)

No.	Source	Number of Publications	Publisher
1.	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	4	Springer
2.	Communications in Computer and Information Science	3	Springer
3.	Proceedings of 6th International	2	Institute of

	Conference of the Immersive Learning Research Network, iLRN 2020		Electrical and Electronics Engineers Inc.
4.	Proceedings of The Australian Conference on Science and Mathematics Education	2	University of Sydney
5.	Journal of Research and Development of Physics Education (JPPF)	1	Universitas Negeri Jakarta
6.	Indonesian Journal of Education (JPI)	1	Universitas Pendidikan Ganesha

Table 1 shows the three sources with the most publications and journals from Indonesia that contribute to the publication of VR research in the field of physics. Based on the literature data, the source with the most publications is Lecture Notes in Computer Science, with four publications. Below is the Journal of Communications in Computer and Information Science with three publications. Meanwhile, the Proceedings of the 6th International Conference of the Immersive Learning Research Network and proceedings of the Australian Conference on Science and Mathematics Education both have two publications. On the other hand, other journals and conferences have one publication. For Indonesia itself, there are Jurnal Penelitian Pendidikan Fisika (JPPF) and Jurnal Pendidikan Indonesia (JPI) which both contribute one publication related to VR in the field of physics.

Table 2. Top publishers on virtual reality (VR) publication in physics (2012-2021)

No.	Publisher	Number of Publications
1.	Institute of Electrical and Electronics Engineers Inc.	14
2.	Springer	14
3.	John Wiley and Sons	5
4.	Kassel University Press GmbH	2
5.	Universitas Negeri Jakarta	1
6.	Universitas Pendidikan Ganesha	1

Table 2 shows the three publishers with the most publications and publishers from Indonesia who contributed to the publication of VR research in the field of physics. Based on the literature data, the publishers with the most publications are the Institute of Electrical and Electronics Engineers Inc. and Springer, with fourteen publications each. Below is John Wiley and Sons with five publications and Kassel University Press GmbH with two publications. Publishers from Indonesia who contribute VR publications in the field of physics are Jakarta State University and the Ganesha University of Education, with one publication each.

Bibliometric Analysis Based on Text Data

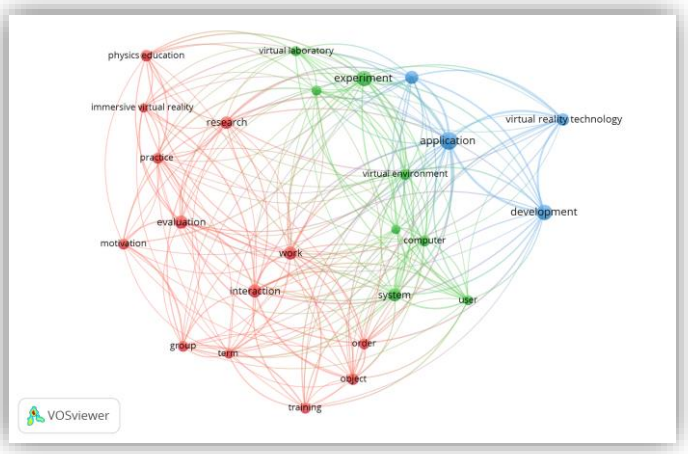
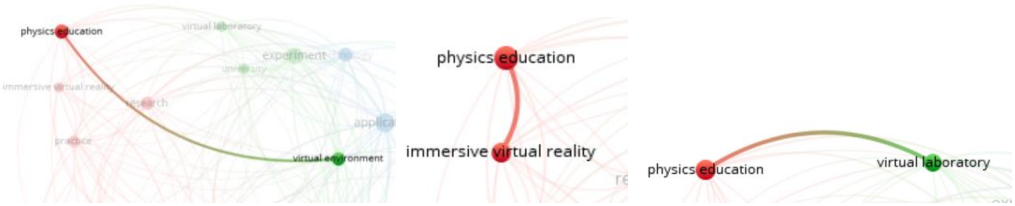


Figure 5. Visualization of the relationship between the author's keywords for virtual reality (VR) research in physics with a minimum of five occurrences

Figure 5 shows the results of mapping relationships between authors' keywords for a minimum number of keyword occurrences five times. In this second mapping, the number of clusters is reduced to three: red with 13 words, green with eight words, and blue with four words. The number of keywords displayed as a whole is 25 words, with a total of 418 links between words as a whole. The keywords displayed are still many, but they are already shrinking. Mapping displays more clearly terms related to virtual reality such as VR technology, virtual environment, virtual laboratory, and immersive virtual reality. Mapping also indicates that VR research conducted in physics is related to the field of experiments and group training.



(a) (b) (c)

Figure 6. Links between keywords physics education with: (a) virtual environment (b); immersive virtual reality; (c) virtual laboratory

Figure 6 shows the relationship of physics education keywords with several keywords related to virtual reality, including virtual environment, immersive virtual reality, and virtual laboratory. Thus, it can be said that physics learning can be done in a virtual environment through the use of VR. Learning physics using VR can give the impression that it affects the actions or actions of learners (immersive). In addition, physics practicum can also be done through a virtual laboratory that requires learners to

conduct experiments or experiments using computer software. The use of virtual laboratories is suitable for use when carrying out e-learning. A virtual laboratory can display a variety of activities, including practice and exercise presentations, simulations, tutorials, games, discoveries, and problem solving (Gunawan, Nisrina, Suranti, Herayanti, & Rahmatiah, 2018).

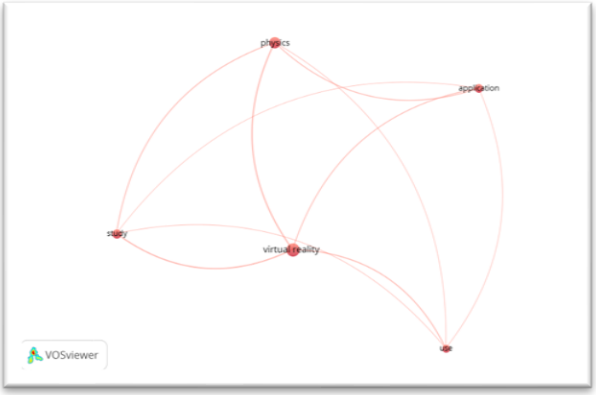


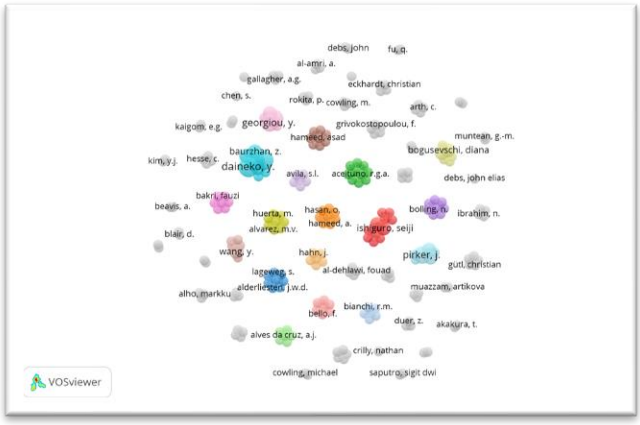
Figure 6. Visualization of the relationship between the author's keywords for virtual reality (VR) research in physics with a minimum of ten occurrences

Figure 7 shows the results of mapping the relationship between the authors' keywords for a minimum number of occurrences of ten times, as suggested by VOSviewer. In this mapping, the number of clusters becomes one only, namely a red cluster with five keywords. Meanwhile, the number of links between keywords is 109, and all words are related. There is a keyword 'use', which means using VR in physics. The keyword 'physics' itself is visible in this mapping, which means the word is often mentioned by the author (34 times). It indicates that VR and physics are pretty interrelated. Then there is the keyword 'application' which indicates that research related to VR in physics focuses more on the application of VR itself (both in learning and other pure research). Finally, there is the keyword 'study', which reinforces the existence of VR research in physics. The complete results are written in table 3 below.

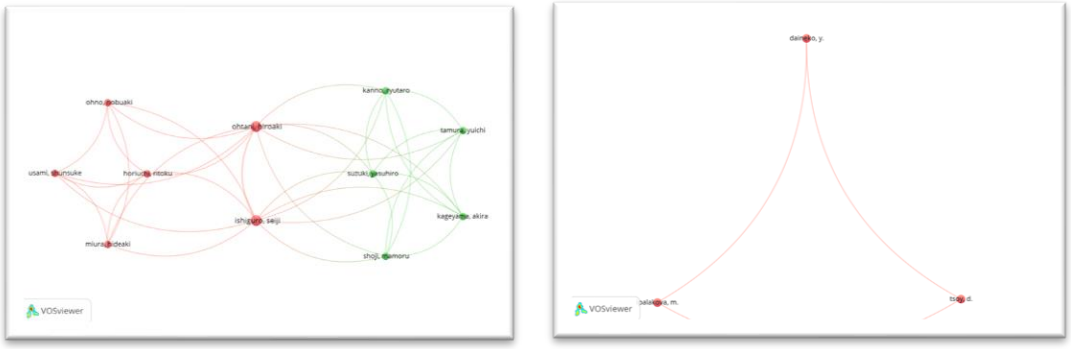
Table 3. Clustering of keywords for meta data of relationships between authors' keywords for virtual reality (VR) research in physics with a minimum of ten occurrences

Cluster	Color	Number of terms	Keyword	Number of occurrences	Total links
1	Red	5	Virtual reality	44	67
			Physics	34	50
			Study	23	41
			Application	14	31
			Use	16	29

Bibliometric Analysis Based on Bibliographic Data



(a)



(a) (b)

Figure 7. Visualization of author names for virtual reality (VR) research in physics with minimum limitation of: (a) one document; (b) one document and eliminating authors without link; (c) four documents

The first mapping is done by displaying the entire author on the topic of VR in physics. The results of bibliometric mapping showed 59 clusters with 5 of them filled with only one author (the 5 authors had no relation to other authors on the topic of VR in physics). Publications on this topic are dominated by 8 clusters consisting of at least 8 authors. The cluster with the most authors is a red cluster consisting of 11 authors (Ohtani et al., 2012; Ohtani et al., 2018) namely N. Ohno, R. Horiuchi, S. Ishiguro, H. Miura, H. Ohtani, S. Usami, A. Kageyama, R. Kanno, M. Shoji, Y. Suzuki, and Y. Tamura. This cluster discusses the use of virtual reality in plasma physics investigations. The green cluster took second place with 10 authors namely Aceituno, D.A.I. Becerra, J.W.T. Chana, A. Figueroa, J.L.H. Mango, G. Paulina, J.A.H. Quispe, G.M.P. Vargas, A.A.P. Vizcarra, and F.G.F. Zamora (Becerra et al., 2017). This cluster discusses the gamification of 3D virtual reality systems to improve understanding of movement in physics.

Meanwhile, the clusters of dark blue, yellow, purple, light blue, orange, and brown have 8 authors. Dark blue cluster consists of J.W.D. Alderliesten, R. Bidarra, B. Dorland, S. Lageweg, J. Mulder, R. Schreuder, L. Van Hal, A. Zaidi, which discusses the delivery of the differences between classical physics and quantum physics by using virtual reality (Dorland et al., 2019). Yellow cluster consists of M. V. Alvarez, J. Espinoza, D. Grijalva, F. Guerrero, M. Huerta, S. Loor, D. Rivas, and G. Vayas, which discusses the use of virtual reality in physics learning (Rivas et al., 2017). Purple cluster consists of N. Bolling, B. Brown, S. Dascalu, V. Le, C.J. Lewis, A.E. Munoz, C. Scully-allison, and W. Zandbergen, which discusses the use of virtual reality in physics laboratories (Munoz et al., 2019). Light blue cluster consists of Z. Baurzhan, Z. Bolatov, Y. Daineko, M. Ipalakova, A. Seitnur, D. Tsoy, Y. Yelgondy, and D. Zhenisov, which discusses the experiences of middle-level students in using virtual reality for physics (Daineko, Ipalakova, & Tsoy, 2019; Daineko et al., 2019; Daineko et al., 2020; Daineko et al., 2020). Orange cluster and brown cluster consist of A. Hameed, O. Hasan, N. Kamal, Z.A. Khan, A. Mahmood, S.B. Mansoor, B. Sadia, and R. Zainab, which discusses virtual reality simulators for laparoscopic training using generic physics engine (Khan et al., 2017). The authors who had no relation to other authors on the topic of VR in physics are S. Chen, M. Neroni, A. Oti, N. Crilly, J.E. Debs, H. Wang, and H. Zhao, which discusses the use of virtual reality for physics learning, including experiment and simulation in teaching (Chen, 2012; Zhao, 2014; Wang, 2018; Debs, 2021; Neroni, Oti, & Crilly, 2021).

The second mapping is done with restrictions where it displays authors with at least one publication, but screening ignores the author regardless of the author without link in accordance with the advice of VOSviewer. The results showed a decrease in the number of clusters to only two clusters, a red cluster and a green cluster with five authors each. The two clusters are interrelated so that they can be considered as one group. If you pay attention, the names of the authors listed on the two clusters are the names of authors from Japan. This means that there is a link between Japanese writers who are constructive for the sake of VR research in physics. When viewed from the size of the circle, the names of authors who have a close relationship with other authors regarding the publication of VR research in physics are Hiroaki Ohtani and Seiji Ishiguro. Both are connected with each author who is in the mapping group above, which discusses the use of virtual reality in plasma physics investigations.

The third mapping is carried out with restrictions where it displays authors with a minimum of four publications, according to the advice of VOSviewer. The results showed three names of authors, namely Y. Daineko, M. Ipalakova, and D. Tsoy who have 4 publications and 8 citations. From the name displayed, the result is different from the previous mapping dominated by writers from Japan. After further investigation, the three apparently wrote four publications together. The three authors are from the International Information Technology University, Kazakhstan.

▪ CONCLUSION

The results show that the trend in VR research increased annually. In one decade, from 2012 to 2021, 68 published papers indicated the growth of VR research in Physics education. About 60% of papers were published in conference proceedings. The mapping of papers' origin identified the United States as the top country contributing to

VR research publications and the leading publishers placed by the Institute of Electrical and Electronics Engineers Inc. and Springer. It is clear that VR research has been growing well in developed countries. Meanwhile, developing countries seem to follow the trend that can be seen from the author's origins. The top three authors were identified from Kazakhstan, namely Y. Daineko, M. Ipalakova, and D. Tsoy. Indonesia also contributed with two publications on this topic from Jurnal Penelitian Pendidikan Fisika (JPPF) and Jurnal Pendidikan Indonesia (JPI). Based on keywords mapping, there are at least five keywords mentioned by authors on this topic, namely virtual reality, physics, application, study, and use. In addition, this study also found that the form of using VR in physics is dominated by the field of education, which is the use of the virtual world in explaining physical materials and virtual laboratories as tools to conduct physics experiments. It means that VR research in physics is mainly done as teaching learning activities setting, and it can be a recommendation for other researchers to develop the research topic in the future. In addition, the authors with the most contributions to VR research in the field of physics are Daineko, Y., Ipalakova, M., and Tsoy, D., who come from one institution in Kazakhstan.

In brief, the trend of VR research in physics suggested a potential advance technology-based research and development in the education sector. Although this study has limitations in exploring the trend based on specific keywords, periods, and sources, these bibliometric study results are valued as a stepping stone in framing VR research in the future.

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