Global Trend On Used Immersive Virtual Reality In Science Education: Bibliometric Analysis

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REVIEW ARTICLE **Setiawan & Winarno**

Global Trend On Used Immersive Virtual Reality In Science Education: Bibliometric Analysis

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Abstrak

Sains merupakan mata pelajaran yang dianggap menantang oleh banyak siswa karena konsepnya yang abstrak. Teknologi Realitas Virtual Imersif (IVR) telah terbukti meningkatkan efektivitas pembelajaran sains dibandingkan dengan metode tradisional. Studi ini mengkaji perkembangan dan tren IVR dalam pendidikan sains melalui analisis bibliometrik. Data dikumpulkan menggunakan pencarian elektronik pada tanggal 12 Juni 2023, dengan kata kunci "realitas virtual imersif ATAU IVR" DAN "pendidikan sains." Temuan tersebut mengungkap semakin banyaknya publikasi tentang IVR dalam pendidikan sains, dengan kesenjangan yang nyata dalam studi selama tahun 2018 dan 2019. Karya Liu R. dkk. menonjol sebagai artikel yang paling banyak dikutip di bidang tersebut. Kata kunci seperti "pembelajaran virtual imersif", "IVR", dan "pendidikan sains" terus mendominasi lanskap penelitian. Tinjauan ini menyoroti kemajuan terkini di bidang ini dan mengidentifikasi arah potensial untuk penelitian di masa mendatang, yang menawarkan wawasan berharga tentang peran IVR dalam meningkatkan pendidikan sains.

Abstract

Science is a subject that many students find challenging due to its abstract concepts. Immersive Virtual Reality (IVR) technology has been shown to enhance the effectiveness of science lessons compared to traditional methods. This study examines the development and trends of IVR in science education through bibliometric analysis. The data was collected using an electronic search on June 12th, 2023, with the keywords "immersive virtual reality OR IVR" AND "science education." The findings reveal a growing number of publications on IVR in science education, with a noticeable gap in studies during 2018 and 2019. The work by Liu R. et al. stands out as the most cited article in the field. Keywords like "immersive virtual learning", "IVR", and "science education" continue to dominate the research landscape. This review highlights the recent progress in this area and identifies potential directions for future research, offering valuable insights into the role of IVR in improving science education.

1. INTRODUCTION

Immersive Virtual Reality (IVR) technology has made significant advancements across various fields such as engineering(Wang et al., 2018), medical science (Ammanuel et al., 2019), economics (Rocca et al., 2020), arts and culture (Lee et al., 2020), and education (Iasha et al., 2022; Meter & Setiawan, 2023; Rachmadtullah et al., 2020). IVR allows users to interact with a virtual environment, offering real-time interaction and 3D visualizations that create a more engaging and flexible learning experience (Alpala et al., 2022; Latifah et al., 2023). Research highlights several advantages of IVR, including enabling learning experiences not possible in the real world (Febriyanti et al., 2022; Radianti et al., 2020), enhancing student participation (Di Natale et al., 2020; Zulela et al., 2022), and improving motivation and attention levels (Papanastasiou et al., 2019; Sumilat et al., 2022). Additionally, IVR can reduce time, space, and cost constraints (Marks & Thomas, 2022; Sumantri et al., 2022),

Science is often perceived as a difficult subject due to its abstract concepts (Iasha et al., 2020; Tomas et al., 2019). The learning of science can be made more meaningful if students directly interact with the phenomena being studied. IVR technology has been shown to be more effective than traditional methods in teaching abstract scientific concepts. By providing a virtual environment that visualizes complex phenomena, IVR helps students grasp difficult topics and visualize events that are typically invisible or hard to conceptualize (Setiawan et al., 2017; Tomlinson et al., 2019).

While several reviews have examined the use of IVR in various educational contexts, only a limited number focus on science education specifically. Previous reviews have explored aspects such as learning theory in IVR design (Lui et al., 2023), the design and evaluation of VR-based learning in science (Matovu et al., 2022), and and the enhancement of K-12 science education with VR/AR (Zhang & Wang, 2021). Notably, a significant gap exists in the literature concerning the development trends of IVR in science education, particularly in relation to the growth of publications, citation patterns, and the evolving usage of keywords within this specific area.

This study aims to address these gaps by conducting a bibliometric mapping analysis focused on Immersive Virtual Reality (IVR) in science education. Unlike previous reviews, this research specifically analyzes how the field has evolved over time through publication trends, citation data, and keyword usage. By utilizing the VOSviewer program for bibliometric mapping, this study offers a detailed analysis of the most frequently used keywords, the most cited authors and journals, and key terms that appear in titles, abstracts, and research keywords related to IVR in science education. This analysis not only fills a critical gap in the existing literature but also provides a comprehensive overview of how IVR is shaping science education and its future research directions.

The research questions guiding this study are as follows:

(a) What is the trend of publications on the use of IVR in science education?
(b) Which are the most cited articles that publish articles on the use of IVR in science education?
(c) What is the distribution of the most used keywords in articles about the use of IVR in science education?

2. METHOD

2.1. Study Design

This study was conducted using a bibliometric mapping analysis. A three-step procedure is used for a scientific mapping study, including literature search and data collection, screening, and eligibility(Zupic & Čater, 2015). The bibliometric analysis in this study is based on several criteria, such as annual publications, number of citations, and keywords. This study did not involve any human or animal interactions, and therefore no ethical approval was required.

2.2. Data Collection

The data was obtained through an electronic search and retrieval method on June 12th, 2023. First, the article data was searched on one of the international databases, Scopus (www.scopus.com). Scopus was chosen due to its extensive collection of research papers across multidisciplinary subjects and its high credibility in research indexation.

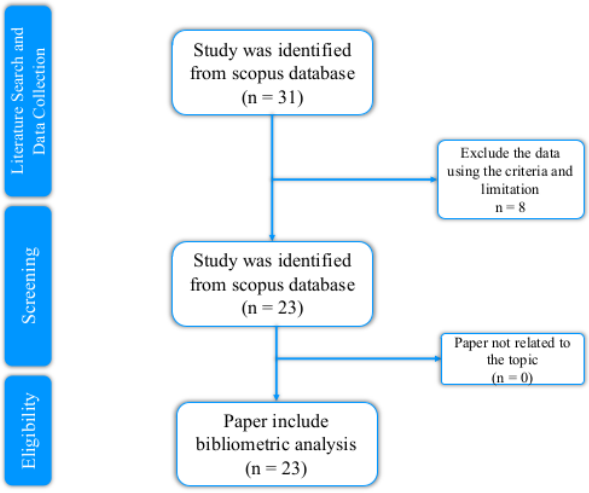

Figure 1. Flowchart of literature selection.

The keyword search was set to include the title, abstract, and keywords. The combination of search strings, operators, and filtering used in this study is: TITLE-ABS-KEY "immersive virtual reality OR IVR" AND "science education". The criteria for data inclusion were: 1) the reviewed study articles must contain one of the keywords in the title, abstract, or keywords, 2) the article must be written in English, and 3) the search period was limited to 2015-2023. The criteria for exclusion are: 1) papers published in languages other than English and 2) editorials, book chapters, books, corrections, brief surveys, reviews, and notes because they are not considered primary sources.

Using these search keywords, we obtained 31 publications in the Scopus database, consisting of 17 journal articles, 13 conference papers, and one other type of document. In this study, the data used only from journal articles (54.84%) and conference papers (41.94%). After filtering out some irrelevant

publications, 23 articles remained for bibliometric analysis. A flowchart of the literature selection is shown in Figure 1.

2.3. 2.3. Data Analysis

Data was downloaded from the Scopus database in research information systems (RIS) formats, including citation information, bibliographic information, abstracts, and keywords. Microsoft Excel and VOSviewer were used for data analysis and visualization(Van Eck & Waltman, 2013). As a powerful science mapping analysis tool, VOSviewer creates collaborative networks for various variables and keywords. Excel was used to analyze descriptive data, such as the trend distribution of publications on topics.

3. RESULT AND DISCUSSION

3.1. Research Result

3.1.1. Publication Trends

Figure 2 shows the distribution of publications and citations over time in the trend analysis for immersive virtual reality in science education. The data reveals that 23 articles published in the Scopus database have been cited 245 times, with an average of 10.65 citations per article and 8.17 citations per year.

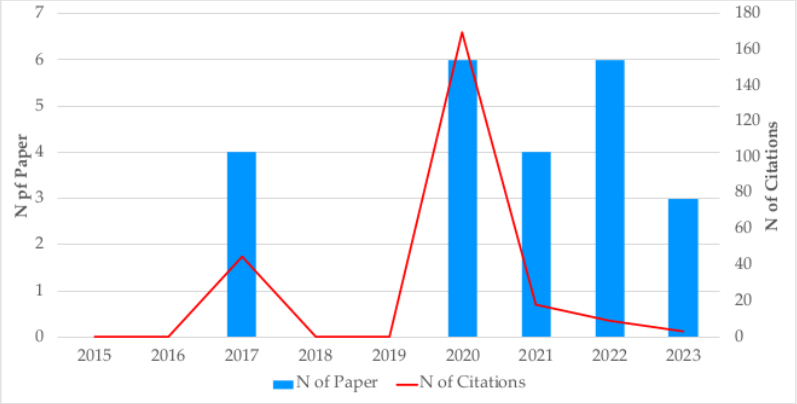

Figure 2. Distribution of articles and citations by year (2015-2023).

Publications related to immersive virtual reality in science education began to emerge in 2017, with four publications and 45 citations in that year. However, there was a noticeable gap in 2018 and 2019, where no publications were related to immersive virtual reality in science education. This dip in publication activity may reflect a broader trend in educational research during these years, possibly due to shifting priorities in research funding, slower adoption of emerging technologies, or a focus on more traditional educational methods.

In contrast, 2020 saw a significant rise in publications, with six publications, which may have been influenced by the global COVID-19 pandemic. The outbreak resulted in the temporary suspension of traditional educational activities (Rachmadtullah et al., 2023; Tarusu et al., 2022), prompting a rapid shift toward online and digital learning platforms. During this transition, immersive virtual reality (IVR) emerged as a promising alternative, as it facilitated online learning experiences that allowed students to interact with virtual environments without physical contact. This shift to virtual learning has profound implications for educators and policy-makers, emphasizing the need for continued investment in digital tools and technologies that support remote and immersive learning experiences (Setiawan et al., 2022; Zawacki-Richter, 2021).

3.1.2. Highly Citation Document

Table 1 presents the five documents with the highest number of citations in the field of Immersive Virtual Reality in Science Education. This information helps identify influential articles in the research area. From the top five papers, the total number of citations (C) was 208, equivalent to 84.90% of the total citations in this study's collection (245 citations). Notably, one article (4.35%) achieved a citation count of over 100, indicating its significant impact on the field.

Table 1. Top five most cited references

No.	Author(s)&Year	Document Title	Publication Source	C
1	Liu, R., Wang, L., Lei, J., Wang, Q., Ren, Y. (2020)	Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons	British Journal of Educational Technology, 51(6), pp. 2034-2049	55
2	Makransky, G., Petersen, G.B., Klingenberg, S. (2020)	Can an immersive virtual reality simulation increase students' interest and career aspirations in science?	British Journal of Educational Technology, 51(6), pp. 2079-2097	51
3	Bujdoso, G., Novac, O.C., Szimkovics, T. (2017)	Developing cognitive processes for improving inventive thinking in system development using a collaborative virtual reality system	8th IEEE ICogInfoCom 2017	45
4	Cheng, K.-H., Tsai, C.-C. (2020)	Students' motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A partial least squares analysis	British Journal of Educational Technology, 51(6), pp. 2139-2158	34
5	Filter, E., Eckes, A., Fiebelkorn, F., Büssing, A.G. (2020)	Virtual reality nature experiences involving wolves on youtube: Presence, emotions, and attitudes in immersive and nonimmersive settings	Sustainability (Switzerland), 12(9),3823	23

3.1.3. Co-Occurrence of Author Keywords

This section presents the frequency of co-occurring keywords in publications related to immersive virtual reality in science education. Table 2 lists the ten most frequent author keywords. The analysis reveals that the most frequently occurring keywords are Immersive Virtual Reality, IVR, and Science Education.

Table 2. The most frequently used keywords

No.	Author Keywords	Occ	TLS[a]
1	Study	19	165
2	Immersive Virtual Reality	19	162
3	Student	15	149
4	Education	14	122
5	Learning	13	120
6	Experience	13	116
7	Science Education	12	117
8	IVR	10	96

[a]TLS: Total link strength

The co-keyword network generated by VOSviewer visualizes the connections between these keywords. The map highlights the relationships between frequently co-occurring keywords, with proximity between nodes representing the strength of their relationship. Larger nodes indicate keywords with higher frequencies, underscoring their significance in the research context.

Figure 3. The most popular author keywords as shown by co-keyword network visualization

Using keywords in research might provide important details about related field investigations. Out of 746 author keywords, 27 were chosen for further examination by using a minimum occurrence criteria of four. Then, based on how closely connected the terms were, they were grouped into clusters, each represented by a different color. The concept-linked keyword groups with similar themes or subjects may be found using this clustering technique.

One notable aspect of the analysis is that the size of each node in the visualization corresponds to the number of occurrences of the respective keyword. This means that keywords with a higher frequency of appearance are represented by larger nodes, highlighting their importance and relevance within the research context. Larger nodes serve as visual indicators of the literature's most significant and frequently discussed concepts or ideas. The significance of node size lies in its ability to capture the attention and

focus given to specific keywords visually. Researchers can quickly identify the keywords that have received the most attention and exploration. This information provides valuable insights into the prevailing research trends and the topics that have generated significant interest among scholars and practitioners.

By analyzing the occurrence and size of nodes, researchers can navigate the vast literature more effectively. They can identify the most relevant and frequently discussed keywords, enabling them to focus on key concepts and themes in their research. This approach helps researchers to gain a deeper understanding of the current state of knowledge in their field and identify potential gaps or areas for further exploration. The data results show 4 clusters, and the most frequently used keyword is Immersive Virtual Reality (19 occurrences, 162 TLS). In addition, five keywords are playing widely used Study (19 occurrences, 165 TLS), Immersive Virtual Reality (19 occurrences, 162 TLS), Student (15 occurrences, 149 TLS), Education (14 occurrences, 122 TLS), and Learning (13 occurrences, 120 TLS). On the map, the main keywords per cluster are immersive virtual learning (red cluster), education (blue cluster), students (green cluster), and impact (yellow). For example, immersive virtual learning is connected to science education, education, virtual reality, learning, students, experience, application, motivation, and others.

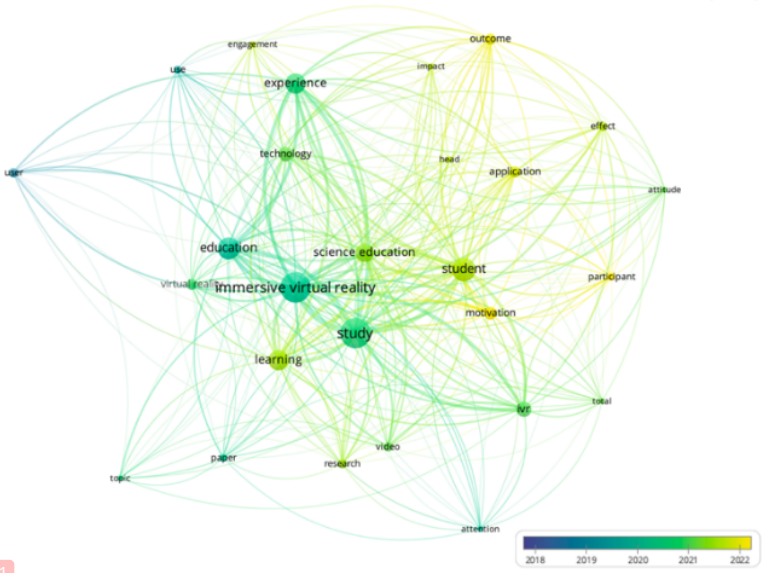

Figure 4. Co-keyword network visualization: distribution of the number of articles using the keywords by year.

Figure 4 shows the distribution of the number of articles using keywords by year. Different colors indicate the publication date for each article based on the keywords. The hottest topics in virtual reality research can be seen in this figure, such as outcomes, motivation, and participants. The findings also show that researchers have turned to research on these topics in recent years.

3.2. Discussion

This study provides a comprehensive perspective on research trends regarding immersive virtual

reality in science education. The growth of publications, top references, and keywords in this research can be examined in depth through bibliometric analysis. Publications related to immersive virtual reality in science education first appeared in 2017. However, there was a decrease in the number of publications in 2018-2019, when no publications were made.

In 2020, there was a significant increase in publications on immersive virtual reality in science education. One of the factors that contributed to this increase was the outbreak of the COVID-19 pandemic, which resulted in the interruption of conventional teaching and learning activities. In response, education has been forced to shift from face-to-face to online learning (Debbarma & Durai, 2021; Pather et al., 2020; Tarusu et al., 2022). In this context, non-physical-based learning media such as immersive virtual reality becomes one of the attractive alternatives to enhance students' learning experience.

The use of immersive virtual reality in science education provides many benefits. This technology allows students to experience a more interactive, immersive, and engaging learning experience (Iasha et al., 2022). They can explore realistic virtual environments, conduct experiments, and directly interact with science objects and phenomena (Jackson & Fagan, 2000). This increases students' interest and motivation to learn and broadens their understanding of abstract science concepts.

Through research focusing on immersive virtual reality in science education, we can identify the latest trends and developments in using this technology to enhance science learning. In today's digital age, where students are increasingly exposed to technology, innovative and engaging learning approaches are key to improving learning outcomes (Timmis et al., 2016). This study contributes to encouraging immersive virtual reality to support student-centered science learning and develop higher-order thinking skills.

Furthermore, it can be observed that the average number of citations per publication varies over time, with the highest peak of citations occurring in 2020, with a total of 55 citations. This indicates significant recognition and influence of the article within the scientific community. Furthermore, the average number of citations per article is 10.65, which means that each article is referred to by an average of more than ten other scientific publications. While the average number of citations per year is 8.17, indicating that each article receives an average of more than eight citations yearly.

The number of citations a scientific article receives indicates its relevance to the scientific research and development (Pinski & Narin, 1976). In this case, five publications had more than ten citations, indicating that these articles were highly influential and recognized by the scientific community. Three other publications received more than five citations, while the rest received less than five. This difference can be attributed to various factors such as the research topic, the methods used, and the impact on relevant research fields.

This discovery can be attributed to recent developments in digital technology. In recent decades, there has been a significant increase in the use of virtual reality-based applications. This aligns with the increasing availability of mobile technologies such as smartphones, tablets, and cell phones that can access and operate virtual reality-based applications (Iasha et al., 2022; Setiawan et al., 2023). These advancements have opened up new opportunities in education, research, and other fields that utilize virtual reality

technology as a powerful tool to present information, visualize abstract concepts, and enhance the learning experience.

Then, the most common author keywords in the selected articles are analyzed. In the document discovery process, keywords play a very important role. Good organization of the article title, abstract, and keywords can significantly impact the ease of finding the article. Based on the analysis of keyword occurrence, it was found that the keywords "learning" and "immersive virtual reality" were most frequently used in the articles discussing immersive virtual reality in science education. These keywords reflect the main focus of the study, which is the application of immersive virtual reality technology in the context of science learning.

In addition, the study also revealed that the keywords "outcomes", "motivation", and "participants" were the most recent keywords to appear in the analyzed literature. These keywords reflect current academic trends in research on immersive virtual learning in science education. These terms are at the core of the discussion on the influence of immersive virtual reality technology on learning outcomes, student motivation, and participant engagement in the context of science education.

4. CONCLUSION

This study reviewed all journal articles on immersive virtual reality, IVR, and science education. All data were obtained from the Scopus database. After filtering to exclude some irrelevant documents based on the inclusion and exclusion criteria, 23 articles remained for bibliometric analysis. The data showed an increase in immersive virtual reality publications in science learning. However, in 2018 and 2019, there were no related studies. The work of Liu R. et al. was the most cited article among the analyzed documents. Keywords such as "immersive virtual learning", "IVR", and "science education" remain the trending keywords in this field. The suggestion for future study is to conduct a deeper analysis of these keywords.

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