JOURNAL OF SCIENCE, TECHNOLOGY, AND SOCIAL INNOVATION
Volume 1, Issue 1, 15-22.
E-ISSN: 3124-260X
https://journal.gomit.id/jstsi/index
DOI: 10.58723/jstsi.v1i1.30

# Bibliometric Analysis of the Use of Virtual Reality Technology in Physics Education: Focus on the Kuula Platform to Improve Understanding of Particle Motion Dynamics Material

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**Article Info**

***Article history:***

Received: September 27, 2025
Revised: October 16, 2025
Accepted: November 2, 2025

***Keywords:***

Bibliometric Study
Kuula Platform
Particle Motion
Physics Education
Virtual Reality

**Abstract**

**ABSTRACT**
Background of study: Physics, particularly the topic of Particle Motion Dynamics, is often considered difficult by students due to its abstract nature, which requires deep visual understanding and complex mathematical applications. VR technology can offer a solution by creating immersive and interactive learning experiences, which are expected to strengthen students' understanding of these concepts
Aims and scope of paper: This research aims to analyze the use of Virtual Reality (VR) technology in physics learning, focusing on the utilization of the Kuula platform to enhance the understanding of the concept of Particle Motion Dynamics in 11th-grade high school students.
Methods: In this study, a bibliometric analysis was conducted to explore literature trends related to the use of VR in physics education, by examining articles related to the Kuula platform and particle motion dynamics through Scopus data (2020–2025).
Result: The analysis results show that although the use of VR in education has been widely implemented, the utilization of the Kuula platform, particularly in teaching abstract physics, is still limited. Furthermore, this research identifies the main challenges in adopting VR technology, including educator resistance and existing resource limitations.
Conclusion: Overall, these findings underscore the importance of innovation in physics education through VR technology to enhance students' conceptual understanding, and suggest the need for further research to optimize the implementation of Kuula-based VR in the educational curriculum.

**To cite this article:** Rahayu, P. W., Risdianto, E., & Purwanto, A. (2025). Bibliometric Analysis of the Use of Virtual Reality Technology in Physics Education: Focus on the Kuula Platform to Improve Understanding of Particle Motion Dynamics Material. Journal of Science, Technology, and Social Innovation, 1(1), 15–22. Retrieved from https://journal.gomit.id/jstsi/article/view/30



## INTRODUCTION

Education is an important component in the development of human resources because it serves as a foundation for improving the well-being of society and individuals. Education helps someone become better in various aspects of life, including in professional and social environments. Curriculum innovation and teaching methods are also important for enhancing the effectiveness of education (Sriyulianingsih et al., 2023) . In addition to internalizing principles relevant to the modern world, high-quality education helps foster innovative and highly competitive human resources (Melani et al., 2023; Yanti & Hamdu, 2021) . Therefore, education not only helps disseminate information but also contributes to the progress of the nation and the quality of life of the community (Ependi & Pratiwi, 2020; Wahyuni & Sunarti, 2023) . Students must master critical thinking skills, digital literacy, and conceptual understanding to face the challenges of 21st-century

learning. Students must possess strong multiliteracy skills to effectively participate in a complex society due to globalization and technological advancements (Prihatini & Sugiarti, 2022; Puri et al., 2022) . Thus, project-based learning, among other innovative pedagogical approaches, can help develop these skills in a fun and beneficial way (Anggraini et al., 2020; Atmaja et al., 2020) . Therefore, it is expected that students not only master academic knowledge but also acquire the skills necessary to solve problems that arise in daily life (Muntamah & Fardana, 2024).

Since the 2022/2023 academic year, the independent curriculum in Indonesia has focused on 21st-century skills such as creativity, critical thinking, and collaboration (Salim, 2023; Wijayanti et al., 2023) . It is hoped that this curriculum not only encourages students to try new things but also allows educators to use more flexible and project-based learning approaches (Handayani et al., 2023; Tami & Friyatmi, 2023) . In response to social and technological developments, Physics is often considered a difficult subject due to its abstract nature, which requires a deep understanding of concepts and complex mathematical applications. Additionally, students often struggle to grasp physics concepts because there is a gap between what they understand in their schools and what is taught in the curriculum (Agustin et al., 2021; Lolita et al., 2020).

The emergence of Virtual Reality (VR) technology has created a more immersive and interactive learning experience. VR is an innovative learning medium that allows students to engage directly in a simulated learning environment. This can enhance students' understanding of the material, especially in complex fields such as health and anatomy (Ryan et al., 2022; Zhao et al., 2020) . However, the adoption of this technology also faces challenges. Instructors who are accustomed to conventional methods oppose it (Fransson et al., 2020; Pletz, 2021). In order for VR to be optimally integrated into the educational curriculum, this challenge must be addressed (Han et al., 2022). The potential of virtual reality as a learning tool is expected to continue increasing as the price of the technology develops (Fransson et al., 2020; Smirnova et al., 2020) . The use of virtual reality (VR) technology in education has many advantages. First, virtual reality supports student engagement and allows them to experience more realistic and immersive learning experiences. These three-dimensional environment simulations allow students to interact directly with learning objects, which is expected to enhance their conceptual understanding of the taught topics (Saputro et al., 2023; Setyawati & Putra, 2021) Students can become more emotionally and cognitively engaged because VR technology can increase their interest and motivation to learn. Overall, the application of VR in education can help transform conventional teaching methods into more interactive and effective ones.

Leveraging the rapidly evolving Metaverse technology, Kuula is an easily accessible media platform for the development and dissemination of virtual reality (VR) content. This platform allows users to create and share 3D content effortlessly, fostering an inclusive environment for both professional and amateur content creators (Hamid et al., 2023; Jagatheesaperumal et al., 2024) Many studies show that Virtual Reality (VR)-based media are effective in education, including in the field of science. Jong et al. explain the use of VR in geography education, where this technology offers interactive experiences that support inquiry-based learning (Jong et al., 2020). Further research by Xiao et al. emphasizes VR's ability to enhance spatial perception and creativity, which are important aspects in science education and environmental design (Xiao et al., 2023) . Additionally, Kim and Park highlight how VR can enhance the clinical skills of nursing students, demonstrating the relevance of VR in health education, which also encompasses scientific aspects (Kim & Park, 2024). The use of VR in education not only enhances student engagement but also provides a safe and controlled environment for experimentation and in-depth learning (Lie et al., 2022). Further development in the application of VR in educational curricula shows the great potential of this technology to revolutionize the way students learn across various disciplines, including science (Hu, 2023).

Previous studies have shown that using Virtual Reality (VR) technology in education improves learning outcomes. Specifically, VR affects student engagement, motivation, and the ability to visualize abstract concepts. Similarly, Chuang et al. demonstrate that VR applications designed for rigorous training or realistic simulations are more enjoyable for users compared to conventional

methods, and that high-quality VR systems enhance user interaction and facilitate immersive learning environments that support experiential knowledge acquisition (Yuan, 2024). Additionally, virtual reality enhances learning by increasing enjoyment, retention, and engagement (Daurrohmah, 2023) . Beyond these findings, Iasha et al. state that virtual reality has the ability to enhance cultural education by providing engaging and inclusive experiences that motivate students (Iasha et al., 2023) . Together, these references demonstrate the transformational role of VR in enhancing educational effectiveness and student engagement.

Based on bibliometric analysis using the VOSviewer application, it shows that conceptual understanding has become the main focus in physics education research. This is evidenced by the fact that the keywords are at the center of the network and are related to many other terms, such as media, education, computation, misconceptions, and simulation. This interconnectedness indicates that researchers have devoted significant attention to developing learning strategies aimed at enhancing students' understanding of concepts in various contexts of physics education. However, further analysis shows that the mapping findings do not indicate a direct relationship between these topics and Virtual Reality technology, specific platforms like Kuula, or complex and abstract materials such as Particle Motion Dynamics. These facts indicate that there has not been much research explicitly developing virtual reality-based learning media focused on particle motion dynamics in high schools, even though the topic requires a strong understanding of spatial visualization and vectors. As a result, the development of innovative learning media based on virtual reality with the help of the Kuula platform.

The results of topic trend visualization with overlay mapping also show how the focus of research has evolved over time. Keywords such as media, educational computing, and inventory ideas continue to show colors indicating that these issues are emerging more recently. However, the words "virtual reality" and "Kuula" do not appear in that cluster. This indicates that there has not been much research specifically utilizing Kuula platform-based virtual reality technology as a medium for teaching physics in high schools. Furthermore, there has been no research that directly integrates virtual reality technology into the teaching of particle motion dynamics, even though this material is very interesting to visualize. Therefore, two main elements of this research have been updated. First, the Kuula platform as a VR learning tool for physics material is still new and has not been extensively studied in the context of high school. Second, the research specifically focuses on creating media that can help students better understand the dynamics of particle motion, an approach that has not been widely used in the previous literature. It is hoped that the combination of technological methods and the characteristics of this material will help develop a more efficient, creative, and modern-compliant physics learning model.

This research aims to develop physics learning media based on Virtual Reality (VR) using the Kuula platform to enhance students' conceptual understanding of the Particle Motion Dynamics material in the 11th grade of high school. Additionally, this research is conducted to fill the literature gap regarding the use of VR technology in physics education, particularly on topics that are abstract and require deep visualization, as well as to evaluate the effectiveness of the media in supporting a more interactive teaching and learning process in accordance with the demands of the Merdeka Curriculum.

## METHOD

This research uses bibliometric analysis methods to examine trends in the use of Virtual Reality (VR) technology in physics education, focusing on the Kuula platform and the topic of particle motion dynamics. This type of research is quantitative with a descriptive approach that emphasizes the identification of scientific publication patterns, keyword networks, and author productivity over a specific period.

The object of this research is scientific documents obtained from the Scopus database, using five main keywords: (1)"Virtual Reality in Physics Education," (2)"Conceptual Understanding in Physics, "(3)"Virtual Reality-Based Learning Media," (4)"Particle Motion Dynamics," and (5)"Conceptual

Understanding." Data is filtered based on the publication years 2020 to 2025 to ensure relevance to the current context.

The research procedure begins with searching for articles in the Scopus database using the five keywords. The search results are then downloaded in CSV format, combined into a single file using the files2zip.com website, and cleaned of duplicates and potential bias using the OpenRefine application. After the cleaning process, the data was analyzed using the Biblioshiny application to obtain bibliometric information, such as keyword metadata, annual publication growth, citations per article, a list of core journals, and topic relationship maps. The analysis results were then visualized using VOSviewer, both in the form of overlay visualization and network visualization, to map the relationships between articles, authors, and research topics. Data collection was conducted online through the exploration of scientific publication metadata and quantitative analysis of all the articles that were successfully gathered. The main instruments used include the Scopus database, OpenRefine software, the Biblioshiny application (based on R), and VOSviewer as a visualization tool.
Data analysis is conducted by examining the emergence of keywords, trends in publication growth, and the interconnections between researchers and topics. This analysis also includes the identification of core journals using Bradford's law, as well as mapping the productivity of countries and authors based on the most relevant publications. The limitations of this research lie in the data source, which is solely from Scopus, and the language of the articles, which is restricted to English, potentially excluding all relevant publications in other languages or those that have not yet been indexed.

**Figures And Tables**
Table 1 Number of Search Result Documents Based on Keywords.

**Table 1.** Number of Search Result Documents Based on Keywords

| Kata Kunci | Jumlah Awal | Setelah Disaring (2020–2025) |
|---|---|---|
| Virtual Reality in Physics Education | 4 | 4 |
| Conceptual Understanding in Physics | 34 | 16 |
| Virtual Reality-Based Learning Media | 10 | 8 |
| Particle Motion Dynamics | 12 | 3 |
| Conceptual Understanding | 10.833 | 60 |

Figure 1 is a picture of the bibliometrix analysis flow.

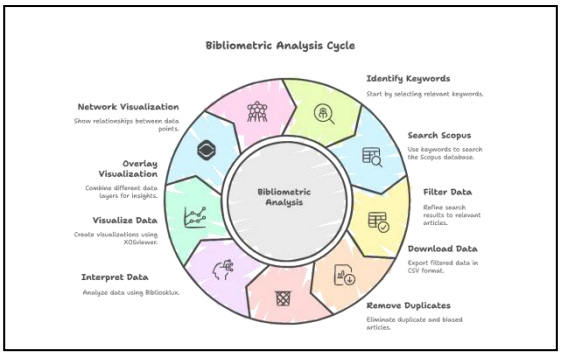


**Figure 1**. Bibliometrix analysis flow.

## RESULTS AND DISCUSSION

### 1. Results

The results of this study indicate that out of a total of 87 documents analyzed using a bibliometric approach through the Scopus database (period 2020–2025), the most dominant topic in physics

education is conceptual understanding. The keyword is centrally positioned in the co-occurrence keyword network and is connected to many other terms, such as education computing, simulation, and media. However, topics such as virtual reality, Kuula, and particle motion dynamics do not appear in the main cluster, indicating that there has not been much research explicitly addressing the use of the Kuula platform in the context of physics learning on abstract topics such as particle motion dynamics. Visualization with VOSviewer in the form of overlay and network visualization shows a clear separation between popular keywords and the topics that are the focus of this study. The growth in the number of publications each year is fluctuating, peaking in 2024 (20 documents). Nevertheless, the annual growth rate of publications shows a negative figure of -1.37%. The average citations per document are 8.93, with author participation from 294 individuals and an international collaboration rate of 22.99%.

## 2. Discussion

These findings indicate that although Virtual Reality technology has been widely used in education, the utilization of the Kuula platform as an interactive learning medium for abstract materials has not yet been extensively explored. The dominance of conceptual understanding in the bibliometric results indicates the importance of concept comprehension in physics education, yet few have integrated it with VR technology in the context of secondary education. This condition indicates a gap between the potential of technology and teaching practices in the field. In fact, Kuula as a VR-based platform has the capability to present a 360° visual environment that greatly supports the visual representation of physics concepts such as motion, force, and trajectory. The minimal use of Kuula-based VR in scientific literature, especially those focused on particle motion dynamics, opens up opportunities for the development of more innovative learning media, in line with the spirit of the Merdeka Curriculum which emphasizes the use of technology and project-based learning.

### 2.1 Implications

The implication of these findings is the need for systematic efforts to integrate VR platforms like Kuula into the development of physics learning media. Visualizing abstract physics concepts through VR can help enhance students' conceptual understanding, while also addressing the challenges of 21st-century learning that demand more interactive, contextual, and technology-based approaches.

### 2.2 Research contribution

This research contributes by mapping the scientific literature related to the use of VR technology in physics education and identifying research gaps in the context of using the Kuula platform. These results serve as a foundation for the development of a VR-based learning model specifically designed for the topic of particle motion dynamics, which has not been extensively studied before.

### 2.3 Limitations

This research has limitations on the scope of data, which only comes from the Scopus database and is restricted to English-language articles within the period from 2020 to 2025. Additionally, the approach used is bibliometric, so it has not yet tested the effectiveness of VR media directly in physics learning in the classroom.

### 2.4 Suggestions

Further research is recommended to develop a prototype of Kuula-based learning media and conduct direct trials in high schools to determine its effectiveness in enhancing student understanding. Additionally, further studies could expand the database and include literature from various languages and sources to obtain a more comprehensive picture.

## CONCLUSION

The conclusion of this study is that the development of physics learning media based on Virtual Reality (VR) with the help of the Kuula platform shows significant potential to enhance students' understanding of concepts in the Particle Motion Dynamics material in the 11th grade of high

school. Bibliometric analysis reveals that although research on VR in physics education has developed, the integration of the Kuula platform and the focus on abstract materials such as Particle Motion Dynamics are still rarely explored. This study emphasizes the importance of innovation in physics education through immersive technologies such as VR, which can facilitate the visualization of complex concepts and enhance student engagement. These findings also highlight the need for further research to optimize the use of VR in the educational curriculum, as well as to address challenges such as technology adoption by educators and resource limitations. Thus, this research makes an important contribution to the development of more interactive and effective learning methods in the digital era.

## ACKNOWLEDGMENT

The author expresses gratitude to the team of supervising lecturers and colleagues within the Physics Education study program who have provided input, support, and encouragement during the process of writing this article. Thanks, are also extended to the institution and library for providing access to data sources and software used in the bibliometric analysis, as well as to the Scopus database managers who were the primary source of data collection in this research.

## AUTHOR CONTRIBUTION STATEMENT

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