Studies in Bibliometrics of Education and Technology
Homepage: https://scie-journal.net/index.php/SiBET
Email:

p-ISSN:XXXXX; e-ISSN: XXXXX
SiBET, Vol. 1, No. 2, April 2026
Page 41-52
©2026 SiBET

Immersive Technology in Physics Education: A Metadata Analysis From 2011 to 2026

***Afaurina Indriana Safitri[1], Irsyad Yusuf Santoso[2], Cahyo Febri Wijaksono[3]**
[1]Department of Physics, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Indonesia
[2]Master Program of Science Education, Faculty of Mathematics and Natural Science, Universitas Negeri Surabaya, Indonesia
[3]Master in Research and Innovation in Higher Education, Faculty of Management and Business, Tampere University, Finland

Article Info

Article history:

Received: 28 February 2026
Revised: 8 March 2026
Accepted: 22 March 2026
Available Online: 30 April 2026

Keywords:

Augmented Reality
Immersive Technology
Physics Education
Virtual Reality

ABSTRACT

This study aims to analyze the research landscape, publication trends, scientific impact (citation analysis), primary publication sources, affiliations, topic trends, and global collaboration patterns in the field of immersive technology in physics education using a bibliometric approach. Data were obtained from reputable scientific databases and analyzed using Biblioshiny. The results show a significant increase in the number of publications, reflecting the growing attention to the use of immersive technology in physics learning. Citation analysis indicates that scientific impact is still dominated by publications from developed countries and high-capacity research institutions. Leading publication sources and affiliations play a crucial role in the production and dissemination of knowledge in this field. Meanwhile, research topic trends are dominated by virtual reality, augmented reality, and interactive learning. Analysis of the collaboration network reveals that the structure remains fragmented, dominated by the United Kingdom and the United States as primary hubs. On the other hand, Indonesia demonstrates a strategic position with high proximity to other actors, potentially accelerating knowledge diffusion, although its bridging role remains limited. The existence of relatively isolated clusters also indicates gaps in global collaboration. These findings confirm that despite the rapid growth of this field, the distribution of collaboration and scientific contributions remains uneven. Therefore, it is necessary to strengthen more inclusive international collaboration and develop more equitable research to support the sustainable progress of this field.

Check for updates OPEN ACCESS CC BY NC ND

INTRODUCTION

In the context of physics learning, students have various opportunities to access the diverse physics materials provided in the curriculum for their level of education. This diversity of physics material itself includes both abstract and non-abstract concepts (Alter, 2017). When studying abstract concepts, students can be assisted by analogies grounded in everyday phenomena they can, of course, observe directly. However, when a phenomenon within the scope of physics cannot be observed directly, students need an intermediary to understand the underlying concept (Eveline et al., 2019). This condition indicates a gap between the abstract characteristics of physics concepts and students' ability to independently construct conceptual understanding. One intermediary that can be integrated into physics learning is digital learning media, such as immersive technologies, including virtual reality (VR) and other forms (Georgiou et al., 2021). The use of digital technology in learning also aligns with the demands of 21st-century education, which emphasizes integrating technology to enhance learning quality (Moshinski et al., 2021; Zou et al., 2025).

VR is a technology that allows users to directly experience something through a digital environment (Rubio-Tamayo et al., 2017). Through its immersive characteristics, VR can create a more immersive learning experience than conventional media (Klingenberg et al., 2020). In the context of physics education, VR can provide visualizations of abstract concepts such as waves and electric fields, making learning more interactive and engaging (Tarng & Pei, 2023). This technology greatly facilitates students' real-life

experiences with abstract physics concepts (Akdag et al., 2025). Thus, students' conceptual understanding will develop with the help of VR (Salihu & Sabitu, 2024). Furthermore, VR has the potential to increase student motivation, engagement, and critical thinking skills through exploration-based learning experiences (Damaševičius & Sidekerskienė, 2024).

With the rapid development of digital technology over the past decade, the use of VR and other immersive technologies in physics education has increased significantly (Pellas et al., 2021). This is supported by advances in hardware and software, as well as the growing need for flexible and adaptive learning, particularly following the global pandemic that has driven digital transformation in the education sector (Kang, 2021). Although numerous studies on VR in physics education exist, the results are scattered and lack comprehensive analyses mapping publication trends, countries, affiliations, and other aspects (Rojas-Sánchez et al., 2023). Most studies focus on the implementation and effectiveness of the technology, but few examine the field's development at a macro level using bibliometric or metadata analysis (Rojas-Sánchez et al., 2023). Therefore, research on metadata that focuses on these aspects is crucial. This approach is crucial for providing a comprehensive overview of the direction of research development, patterns of scientific collaboration, and potential research gaps that remain open in the future. Therefore, this study has the following objectives:

1. Analyze publication trends, scientific impact (citation analysis), primary publication sources, affiliations, and research topic trends.
2. Analyze scientific collaboration patterns at both author and country levels, and identify gaps and future directions.

RESEARCH METHOD

This research is a systematic literature review conducted by integrating the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. This approach was chosen because it ensures the literature selection process is carried out systematically, transparently, and can be replicated by other researchers (Sarkis-Onofre et al., 2021). This method consists of several stages, including identification, screening, eligibility determination, and selection of the final articles for analysis (Agrawal et al., 2024; Selçuk, 2019). In addition, this study also adopted a bibliometric analysis approach to explore patterns, trends, and research structures in the field of immersive technology in physics education. The following outlines the research flow, integrating the PRISMA method, as shown in Figure 1.

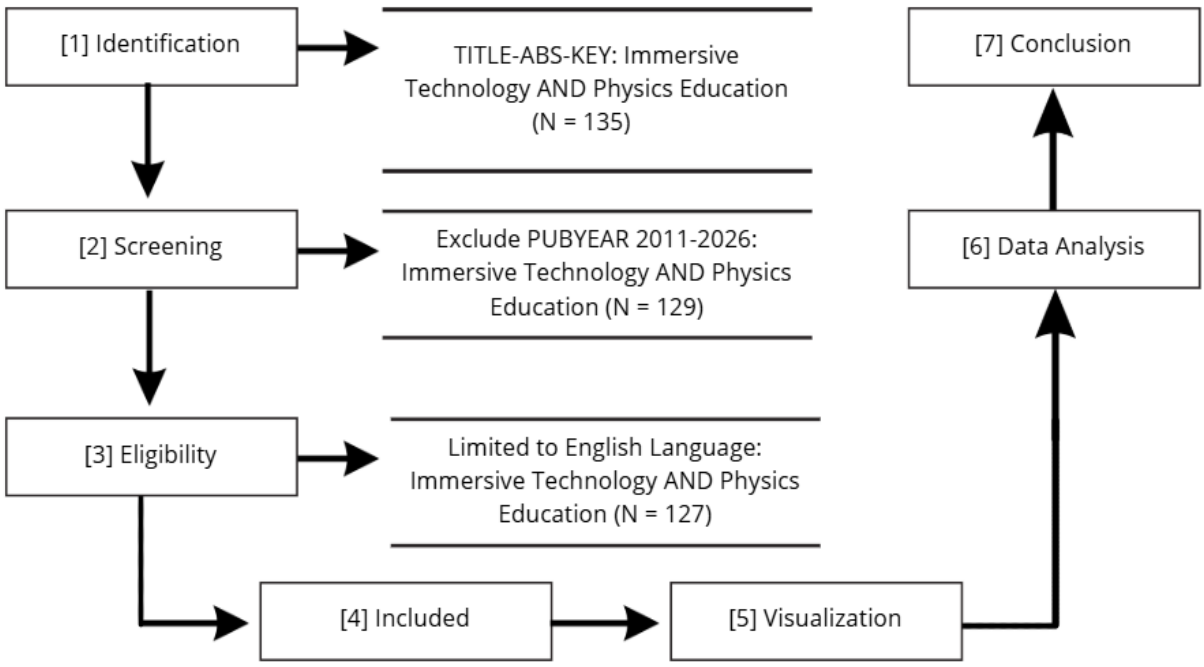


Figure 1. PRISMA Method

In more detail, the identification stage involved a search in Scopus using the string "TITLE-ABS-KEY: immersive technology AND physics education," which returned 135 documents. The Scopus database was selected for its broad coverage and credibility in indexing internationally reputable scientific publications, as it has a large capacity to provide comprehensive sources (Baas et al., 2020; Safitri & Mubarok, 2024; Suprapto et al., 2025). Next, the documents were filtered to the 2011- 2016 time range, reducing the number of documents retrieved to 129. 2011 was chosen because, before that period (1999-2009), research on immersive technology in education, particularly VR, was limited, highlighting the need for further research in 2011. Moreover, the early 2010s represented the initial expansion phase of the development of that technology, as evidenced by the increasing research attention to VR-based learning systems (Hamilton et al., 2021).

After the screening stage, the articles were assessed for eligibility based on a language restriction (English), yielding 127 documents as data sources for analysis. These inclusion criteria aimed to ensure language consistency and facilitate comprehensive content analysis. Furthermore, documents irrelevant to the context of physics education were excluded to maintain the validity of the data. The next stage is to visualize data saved in .csv format within the Biblioshiny software, so that various data can be obtained for use aligned with research needs.

Biblioshiny is used for its ability to generate interactive and informative bibliometric visualizations such as publication trends, citation analysis, author collaboration networks, and keyword co-occurrence (Kumar, 2025; Wu & Ye, 2021). Through this process, research is not only descriptive but also capable of uncovering patterns of relationships among variables in the analyzed literature. Next, the visualized data is analyzed descriptively and interpretively to identify research trends, scientific contributions, and future research directions. This analysis process forms the basis for formulating research conclusions and implications.

RESULTS AND DISCUSSION

Results

Annual Scientific Production and Average Citation Per Year

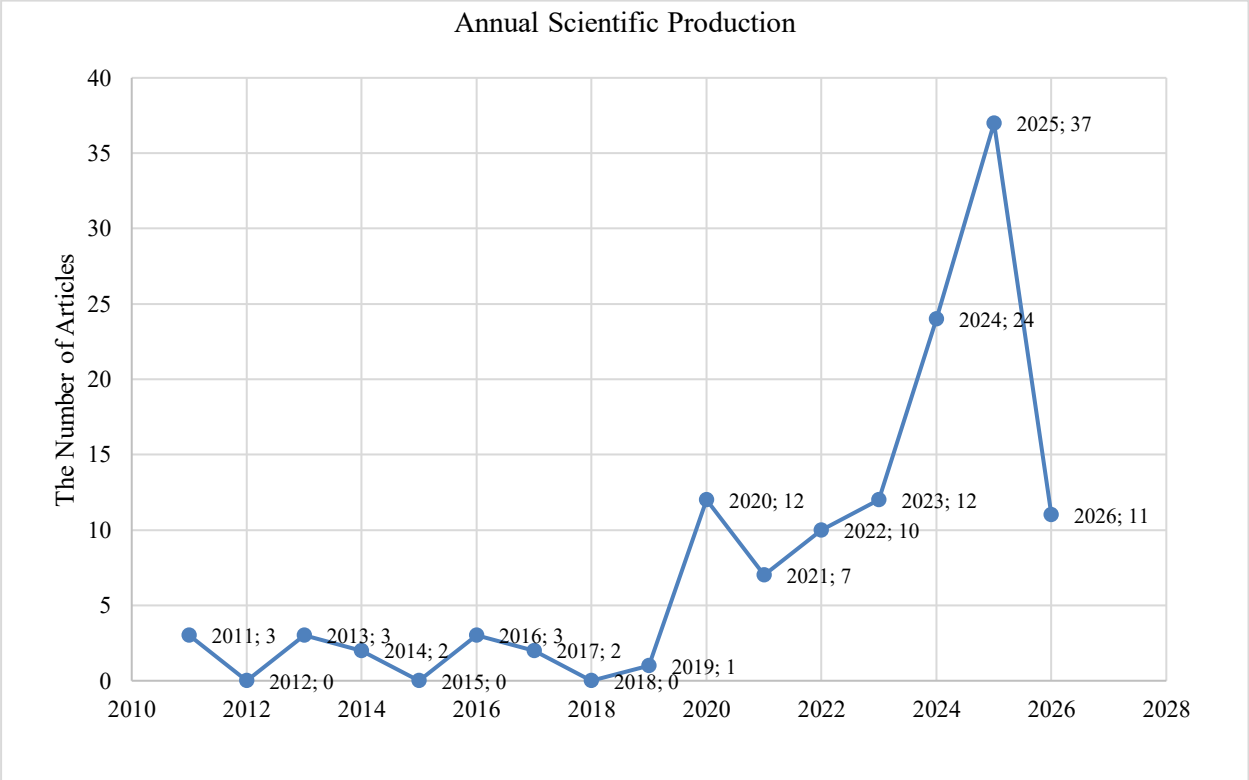


Figure 2. Annual Scientific Production

Figure 2 shows that the publication trend on immersive technology in physics education fluctuated during the initial period, from 2011 to 2019. During this period, the number of publications was relatively

low and unstable, with none appearing in some years, such as 2012, 2015, and 2018. The highest number of articles in the initial period was only 3, as seen in 2011, 2013, and 2016. Entering 2020, there was a significant increase, with the number of publications reaching 12, but it decreased to 7 in 2021. After that, the publication trend continued to consistently increase, peaking in 2025 with 37 articles. However, in 2026, the number decreased to 11 publications.

This significant increase in publications since 2020 indicates increased research attention to the use of immersive technology in physics education (Wang et al., 2025). This is likely influenced by the acceleration of digital transformation in the education sector, particularly since the COVID-19 pandemic, which has driven the widespread use of digital-based learning technologies (Nurhas et al., 2022). Furthermore, the development of increasingly affordable and accessible technologies, such as VR, has contributed to the growing number of research studies in this field. Meanwhile, the decline in the number of publications in 2026 could be due to limited citation time or incomplete indexing, which may not reflect the true situation. In general, this trend indicates that immersive technology in physics education is a rapidly developing research area with significant potential for continued advancement (Prayogi & Verawati, 2024).

Table 1 shows that the average citations per article (MeanTCperArticle) and the average citations per year (MeanTCperYear) show significant variation between years. The highest citation rate was found in 2016, with a MeanTCperArticle of 463.67 and a MeanTCperYear of 42.15, despite the relatively small number of articles, namely only three publications. Furthermore, 2013 and 2021 also showed relatively high citation rates, with MeanTCperYear of 3.62 and 6.02, respectively. Conversely, in more recent years, such as 2024, 2025, and 2026, citation rates tended to be low, with MeanTCperYear below 1, even reaching 0.09 in 2026. This occurred despite the relatively high number of publications in those years, particularly in 2025, when 37 articles were published.

Table 1. The Average Citation Per Year

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
2011	5.67	3	0.35	16
2013	50.67	3	3.62	14
2014	13.00	2	1.00	13
2016	463.67	3	42.15	11
2017	34.00	2	3.40	10
2019	7.00	1	0.88	8
2020	16.83	12	2.40	7
2021	36.14	7	6.02	6
2022	12.20	10	2.44	5
2023	5.75	12	1.44	4
2024	2.12	24	0.71	3
2025	0.49	37	0.24	2
2026	0.09	11	0.09	1

The high average citation rate in the early years, particularly in 2016, indicates that publications during that period had a strong scientific impact and had the potential to become primary references in the field of immersive technology in physics education (Fu & Hughey, 2019; Tahamtan et al., 2016). This could be due to the time accumulation effect, in which older articles have more time to be cited. Conversely, the low citation rate in more recent years does not necessarily indicate low research quality; rather, it is due to limited publication time, meaning articles have not had enough time to be cited by other studies (Taqwa & Panya, 2026). Furthermore, the significant increase in publications in recent years can lead to a more dispersed distribution of citations (Abramo et al., 2016; Bornmann & Leydesdorff, 2017). This pattern indicates a shift from high-impact but limited research in the early period to a growing number of publications in the more recent period, which is still developing in terms of scientific impact.

The Most Relevant Sources

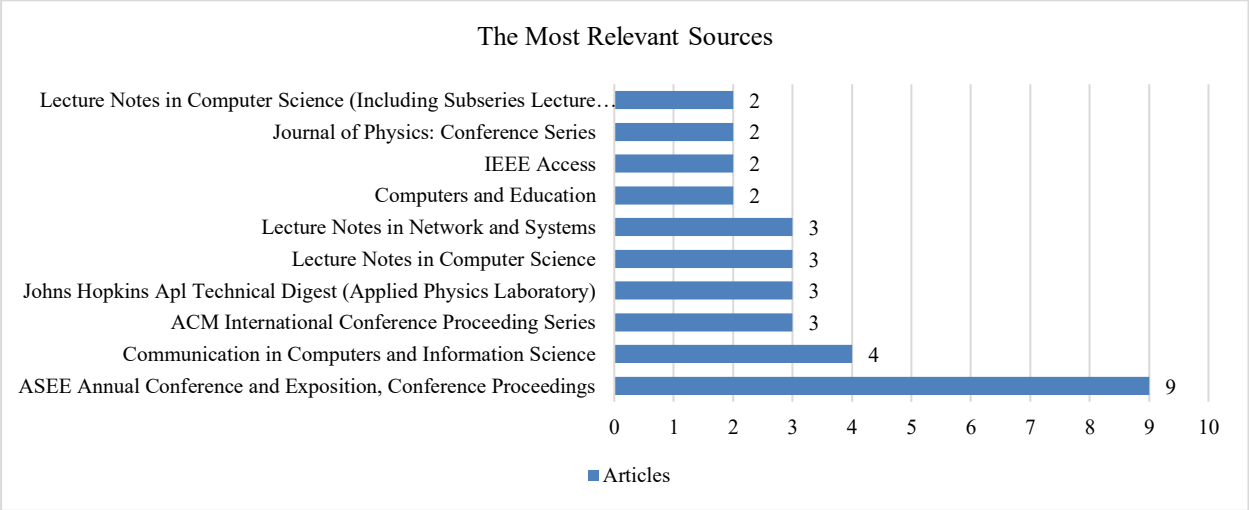


Figure 3. The Most Relevant Sources

The analysis shows that publications on immersive technology in physics education during the 2011–2026 period were dominated by conference proceedings and reputable journals in technology and engineering education. The most productive source was the ASEE Annual Conference and Exposition, which recorded the highest number of articles, namely nine publications, indicating that the engineering education conference forum is a primary platform for disseminating research on this topic. Next, Communication in Computers and Information Science came in second with four articles, followed by several other sources, including the ACM International Conference Proceeding Series, Johns Hopkins APL Technical Digest, Lecture Notes in Computer Science, and Lecture Notes in Network and Systems, each contributing three articles. Meanwhile, other journals and proceedings, such as Computers & Education, IEEE Access, Journal of Physics: Conference Series, and Lecture Notes in Computer Science (Including Subseries), each recorded two publications. This pattern indicates that research on immersive technology in physics education is still developing rapidly within the educational technology-based conference and publication community, which emphasizes the importance of integrating digital innovations in the science learning process.

The Most Relevant Affiliations and Their Production Over Time

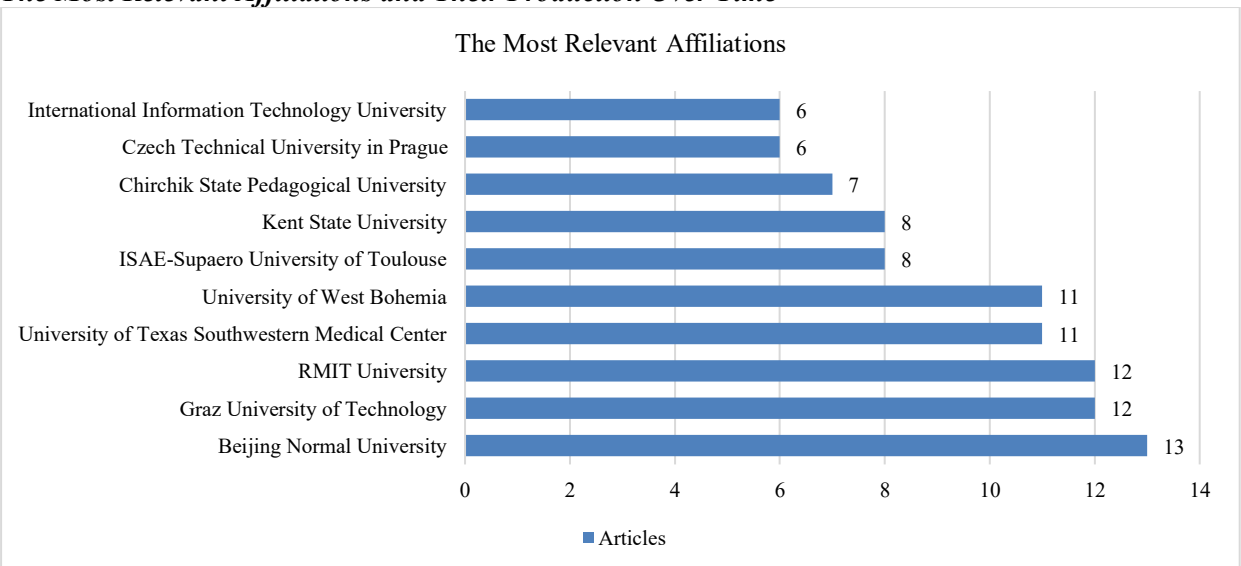


Figure 4. The Most Relevant Affiliations

An analysis of institutional affiliations shows that research contributions on immersive technology in physics education are spread across various international universities with varying levels of productivity. Beijing Normal

University was recorded as the most productive institution, with 13 publications, followed by Graz University of Technology and RMIT University, each with 12 publications. Furthermore, the University of Texas Southwestern Medical Center and the University of West Bohemia showed significant contributions with 11 publications each. Other institutions, such as ISAE-Supaero University of Toulouse and Kent State University, also played an active role with eight publications, while Chirchik State Pedagogical University, Czech Technical University in Prague, and the International Information Technology University showed stable contributions with between six and seven publications. These findings indicate that the development of immersive technology in physics education is a global and multidisciplinary research field, with institutions from Asia, Europe, and North America actively contributing to the development of technology-based learning innovations.

Co-occurrence Network

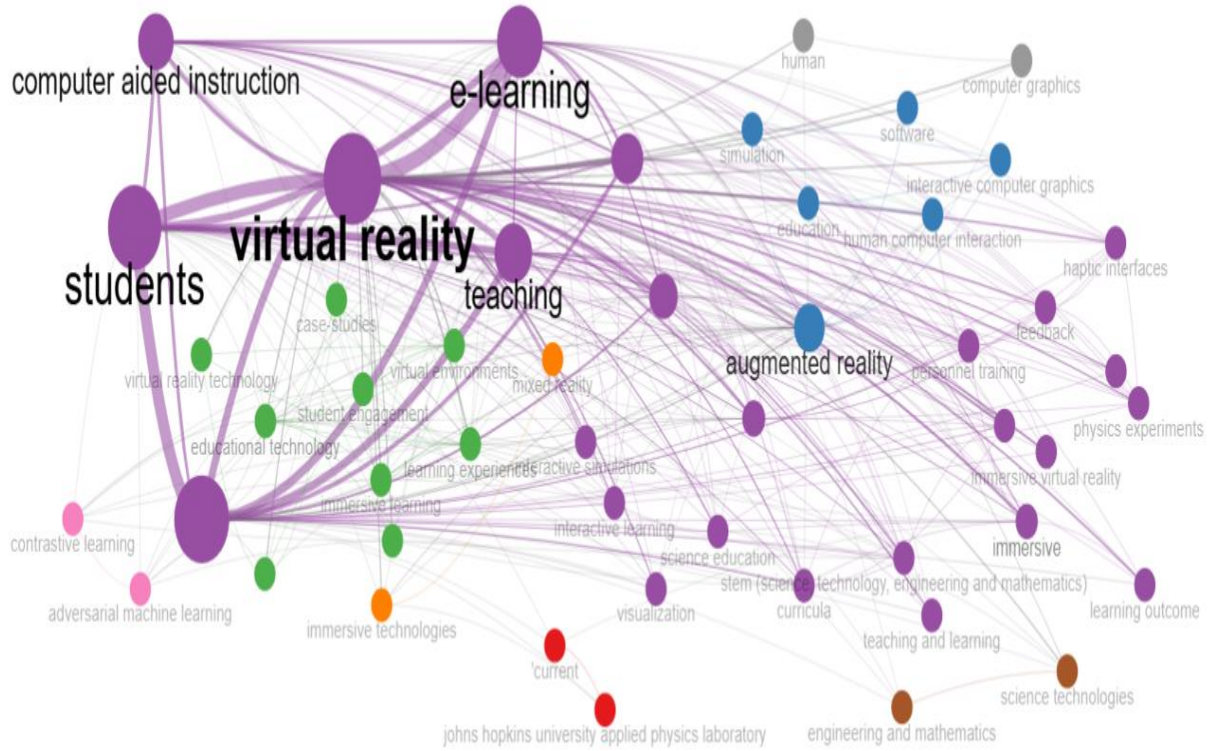


Figure 5. Co-occurrence Network

The results of the co-occurrence network analysis indicate that the research landscape on immersive technology in physics education during 2011–2026 focuses on integrating digital technology into student-centered learning processes. The VR node emerged as the dominant node and had the most extensive connections to other keywords, indicating that this technology is a key foundation for innovation in modern physics learning. The strong link between VR, students, e-learning, and teaching indicates that the research focus is not only on technology development but also on its utilization to enhance student engagement, conceptual understanding, and learning experiences in digital learning environments.

Moreover, the emergence of keywords such as augmented reality, simulation, interactive learning, and physics experiments indicates an expansion of pedagogical approaches that combine immersive technology with experimental practices and visualization of abstract concepts in physics. The resulting cluster structure also demonstrates the interconnectedness between science education, engineering, and technology-enhanced learning, confirming that research in this field is developing multi-disciplinarily and adapting to technology-based educational transformations. Next, this network reflects that immersive technologies, particularly VR, have evolved from being mere visual aids to strategic components in the design of physics learning that is interactive, contextual, and centered on the student's learning experience.

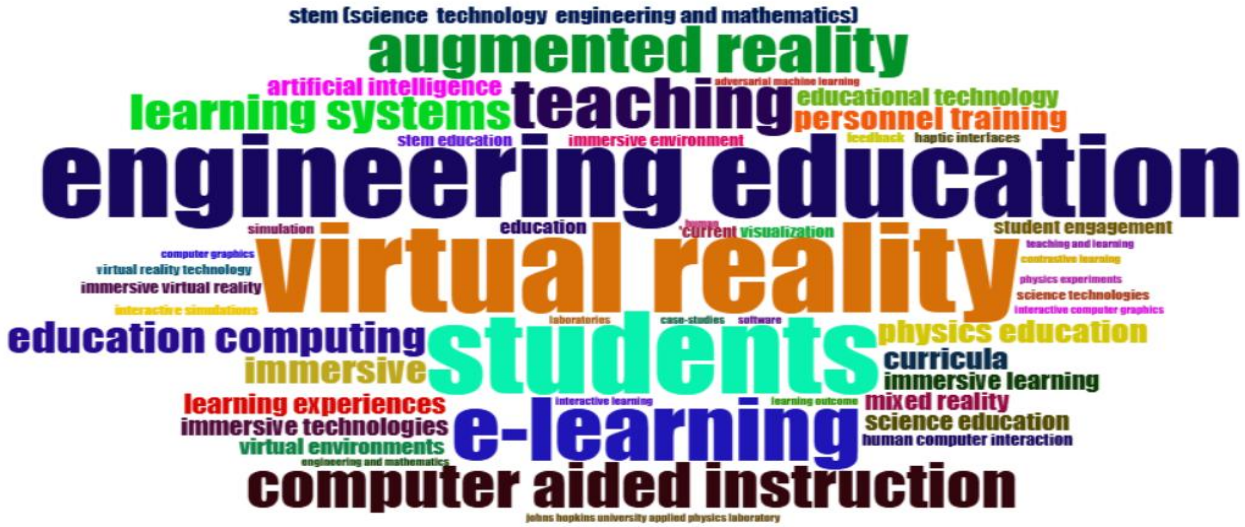


Figure 6. Word Cloud Visualization from Biblioshiny

The word cloud visualization results show that research on immersive technology in physics education for the period 2011–2026 is dominated by several key terms that reflect a focus on integrating immersive technology within engineering education and digital learning. The keyword VR is the most frequent term (46 occurrences), followed by engineering education (43), students (42), and e-learning (32), indicating that virtual reality technology is widely used in engineering education settings to enhance student engagement and learning experiences (Suhail et al., 2024). Furthermore, the terms teaching (26) and augmented reality (24) indicate that research focuses not only on the technology itself, but also on pedagogical strategies and the development of technology-based learning methods. The emergence of keywords such as computer-aided instruction (23), learning systems (18), educational computing (16), and immersive (14) indicates a shift towards more interactive and adaptive computer-based learning systems. The distribution pattern of keywords in this word cloud indicates that the development of immersive technologies, particularly VR and augmented reality, has become a crucial element in the transformation of science and engineering learning, with an emphasis on improving the quality of learning experiences, teaching effectiveness, and the integration of digital technologies in the modern education ecosystem (Álvarez-Marín & Velazquez-Iturbide, 2022).

Author Collaboration Network

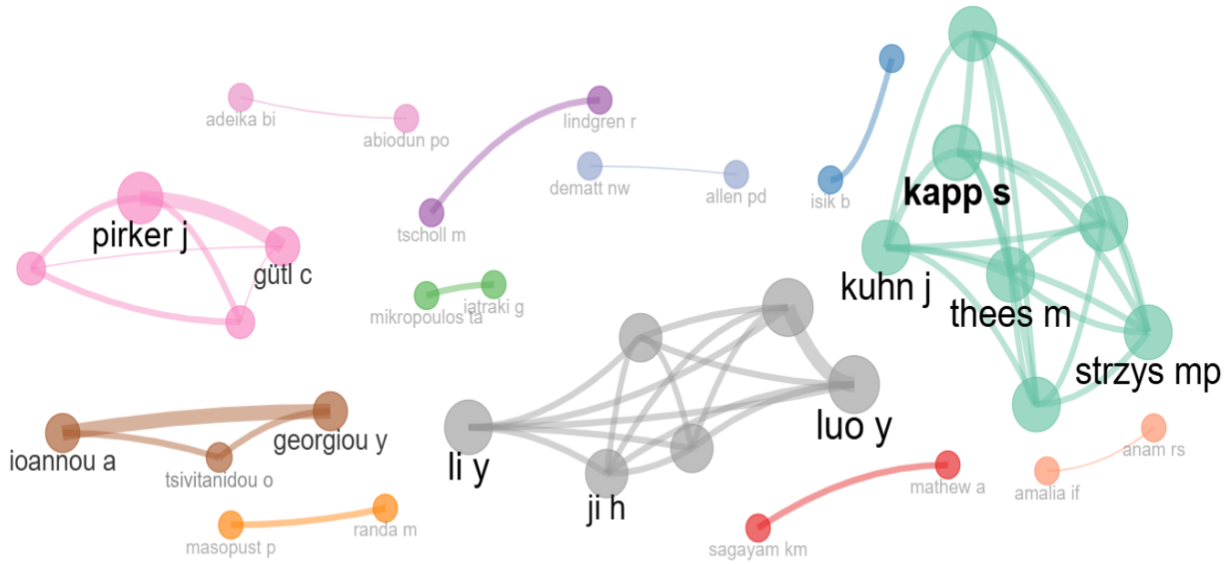


Figure 7. Author Collaboration Network

Author collaboration network analysis shows that collaboration patterns in immersive technology within physics education research from 2011 to 2026 form several relatively separate clusters, each with

strong internal collaboration. The largest cluster is found in the author group led by Marek Thees, Johannes Kuhn, Stefan Kapp, and Mateusz Strzys, demonstrating high connectivity and intensive collaboration in the development of immersive technology for science and engineering learning. Another prominent cluster is the author group of Yuan Luo, Yi Li, and Jianhui Ji, who form a medium-sized collaborative network focused on integrating digital technology into learning environments.

Meanwhile, several smaller clusters, such as those of Pirker, Georgiou, and Ioannou, demonstrate more limited collaboration but remain consistent in their research contributions. The fragmented yet dense network structure within the clusters indicates that research in this field is still developing within specific, team-based research communities, with strong international collaborations that are not yet fully integrated globally. Overall, these findings suggest that the advancement of immersive technology research in education is heavily influenced by the presence of core research groups that serve as centers of innovation and knowledge production, while also opening opportunities to strengthen cross-institutional and cross-national collaboration in the future.

Country Collaboration Network

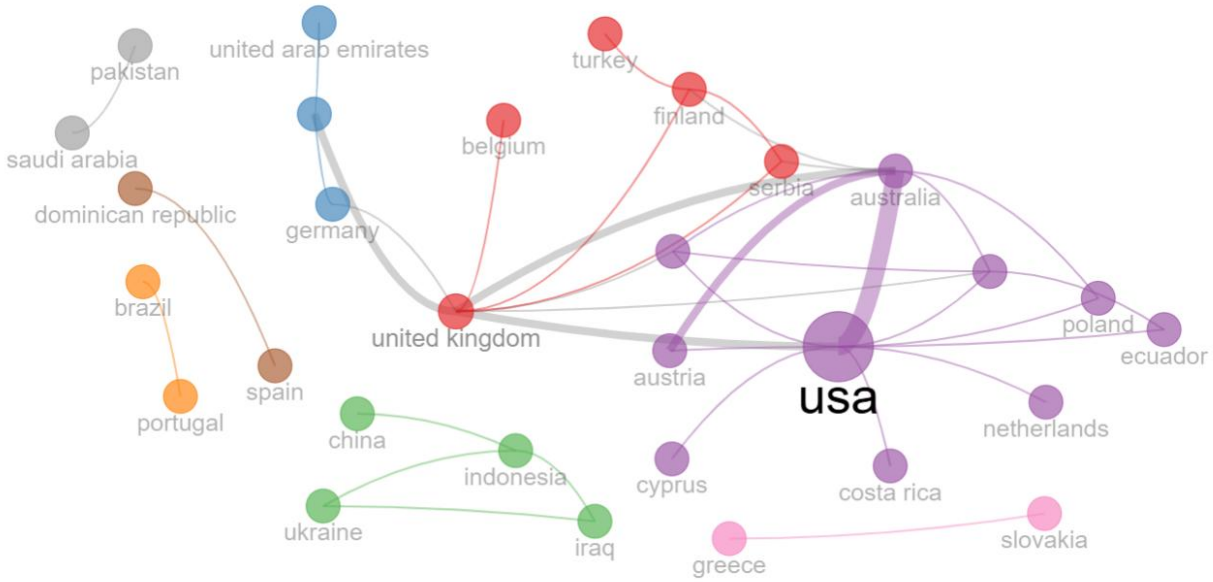


Figure 8. Country Collaboration Network

The latest analysis of country collaboration networks reveals an increasingly complex collaboration structure, yet remains fragmented into several global clusters. The primary cluster is still dominated by developed countries, with the United Kingdom (betweenness = 64,086) and the United States (betweenness = 59,893; highest PageRank = 0.101) as two key actors acting as global bridges in the network. Betweenness indicates a country's role in bridging research collaboration, indicating that the higher the percentage, the more active a country is in holding as a scaffolding in research partnerships (Duggan et al., 2024). Both have strong capabilities for connecting countries across clusters, thereby becoming centers of collaborative flows and knowledge diffusion.

Furthermore, Australia also plays a significant role as a secondary link (betweenness = 26,748), reinforcing the dominance of the global cluster (cluster 4), which appears to be the most extensive and integrated compared to the other clusters. On the other hand, Indonesia again stands out with the highest closeness centrality (0.333) and a relatively high PageRank (0.049), indicating a strategic position in the network for accelerating information access and dissemination, although its bridging role remains limited. Other countries in the Asian cluster, such as China, Ukraine, and Iraq, have relatively high network closeness but are not yet strongly connected to global collaboration hubs. Meanwhile, small clusters, such as those involving Brazil, Portugal, and the Dominican Republic, show a maximum closeness score (1), indicating very close internal connections but isolation from the broader global network.

Table 2. Country Rank

Betweenness	Closeness	Cluster	Node	PageRank
59.893	0.038	4	Usa	0.101
64.086	0.04	1	United Kingdom	0.092
26.748	0.037	4	Australia	0.087
2	0.333	3	Indonesia	0.049
3.274	0.032	4	Italy	0.039
16	0.026	2	Switzerland	0.037
16	0.029	1	Finland	0.036
0	0.25	3	Ukraine	0.033
0	0.25	3	Iraq	0.033
0	1	5	Brazil	0.033
0	1	5	Portugal	0.033
0	1	6	Dominican Republic	0.033
0	0.031	4	Japan	0.031
0	0.028	1	Serbia	0.025
0	0.026	4	Austria	0.024
0	0.026	2	Germany	0.019
0	0.2	3	China	0.019
0	0.024	4	Ecuador	0.018
0	0.026	4	Poland	0.018
0	0.02	1	Turkey	0.013
0	0.019	2	United Arab Emirates	0.013
0	0.024	1	Belgium	0.012
0	0.024	4	Cyprus	0.012
0	0.024	4	Costa Rica	0.012
0	0.024	4	Netherlands	0.012

The implications of these findings confirm that the research collaboration ecosystem for immersive technology in physics education is still dominated by countries with high research capacity, while developing countries tend to occupy peripheral or regional positions. The main gap lies in the lack of cross-cluster integration, particularly between developing countries and global research hubs. Therefore, future research needs to focus on strengthening more inclusive and balanced international collaboration by encouraging the active involvement of developing countries as strategic partners in knowledge production. Furthermore, further studies are needed to identify effective collaboration mechanisms or models to bridge isolated clusters and to explore how countries like Indonesia can elevate their role from mere emerging participants to regional hubs that connect Asian networks with global research hubs.

Discussion

The results of the bibliometric analysis indicate that the research objectives of identifying publication trends, scientific impact, primary sources, affiliations, collaboration patterns, and research topics in the field of immersive technology in physics education have provided a comprehensive picture. In terms of publication trends, there has been a significant increase in the number of articles in recent years, indicating growing academic interest in integrating immersive technology into physics learning. This aligns with the growing need for digital-based pedagogical innovation in today's education.

From a scientific impact perspective, citation analysis shows that research contributions are still dominated by publications from developed countries with high visibility and influence (Iqbal et al., 2018; Tomaszewski, 2023). The primary sources of publications and the most productive affiliations generally come from institutions with strong research capacity that serve as centers for knowledge production and dissemination. This confirms the concentration of academic power in certain institutions with access to greater research resources.

Furthermore, analysis of topic trends via keyword co-occurrence indicates that research in this field focuses on technologies such as VR, augmented reality, and interactive learning approaches to enhance understanding of physics concepts (Sasikumar et al., 2022). However, there are still opportunities for further exploration regarding more contextual pedagogical integration and the evaluation of long-term impacts on learning.

In the context of global collaboration, inter-country collaboration networks exhibit a fragmented structure. Countries such as the United Kingdom and the United States serve as major hubs with significant influence in connecting various actors within the network. Meanwhile, Indonesia demonstrates a strategic position with a high degree of proximity to other actors, although its role as a hub remains limited. This situation indicates that despite the growth of research, the distribution of collaboration and access to global networks remains unequal.

CONCLUSION

This study aims to analyze publication trends, scientific impact, primary sources, affiliations, topic trends, and global collaboration patterns in the field of immersive technology in physics education. The results show a significant increase in publication productivity, reflecting growing academic attention in this field. Scientific impact and major contributions are still dominated by developed countries and institutions with high research capacity, which serve as centers for knowledge development and dissemination.

Furthermore, research topic trends indicate a focus on using immersive technologies, such as VR and augmented reality, to improve the quality of physics learning. However, the global collaboration network remains fragmented, with the United Kingdom and the United States as dominant actors. On the other hand, Indonesia holds strategic potential within the network, although its role is still developing. Overall, this study confirms that despite the rapid growth of this field, gaps remain in the global distribution of collaboration and scientific contributions. Therefore, future research should encourage more inclusive international collaboration, expand the involvement of institutions from developing countries, and explore more contextualized pedagogical innovations to sustainably enhance learning impact.

REFERENCES

Abramo, G., D'Angelo, C. A., & Soldatenkova, A. (2016). The dispersion of the citation distribution of top scientists' publications. *Scientometrics*, *109*(3), 1711–1724. https://doi.org/10.1007/s11192-016-2143-7

Agrawal, S., Oza, P., Kakkar, R., Tanwar, S., Jetani, V., Undhad, J., & Singh, A. (2024). Analysis and recommendation system-based on PRISMA checklist to write systematic review. *Assessing Writing*, *61*, 100866. https://doi.org/10.1016/j.asw.2024.100866

Akdag, M. A., Botev, J., & Rothkugel, S. (2025). Enhancing learning and knowledge retention of abstract physics concepts with virtual reality. *IEEE Transactions on Visualization and Computer Graphics*. https://doi.org/10.1109/TVCG.2025.3616826

Alter, S. (2017). Nothing is more practical than a good conceptual artifact… which may be a theory, framework, model, metaphor, paradigm or perhaps some other abstraction. *Information Systems Journal*, *27*(5), 671–693. https://doi.org/10.1111/isj.12116

Álvarez-Marín, A., & Velazquez-Iturbide, J. A. (2022). Augmented reality and engineering education: A systematic review. *IEEE Transactions on Learning Technologies*, *14*(6), 817–831. https://doi.org.10.1109/TLT.2022.3144356

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377–386. https://doi.org/10.1162/qss_a_00019

Bornmann, L., & Leydesdorff, L. (2017). Skewness of citation impact data and covariates of citation distributions: A large-scale empirical analysis based on Web of Science data. *Journal of Informetrics*, *11*(1), 164–175. https://doi.org/10.1016/j.joi.2016.12.001

Damaševičius, R., & Sidekerskienė, T. (2024). Virtual worlds for learning in metaverse: A narrative review. *Sustainability*, *16*(5), 2032. https://doi.org/10.3390/su16052032

Duggan, E. W., Atwood, G. S., Sanford, J. A., Tsai, M. H., Egbaria, J. K., Carmichael-Tanaka, N., & Outland, N. B. (2024). Using bibliometric data to define and understand publishing network equity in anesthesiology. *Anesthesia & Analgesia*, *139*(5), 944–954.

https://doi.org/10.1213/ANE.0000000000006877
Eveline, E., Jumadi, Wilujeng, I., & Kuswanto, H. (2019). The effect of scaffolding approach assisted by PhET simulation on students' conceptual understanding and students' learning independence in physics. *Journal of Physics: Conference Series*, *1233*(1), 12036. https://doi.org/0.1088/1742-6596/1233/1/012036 https://doi.org/0.1088/1742-6596/1233/1/012036
Fu, D. Y., & Hughey, J. J. (2019). Releasing a preprint is associated with more attention and citations for the peer-reviewed article. *Elife*, *8*, e52646. https://doi.org/10.7554/eLife.52646
Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development*, *69*(6), 3051–3080. https://doi.org/10.1007/s11423-021-10055-y
Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32. https://doi.org/10.1007/S40692-020-00169-2
Iqbal, H. M., Mahmood, K., & Iqbal, S. A. (2018). Factors contributing towards research productivity and visibility: a case study of Pakistan. *Libri*, *68*(2), 85–98. https://doi.org/10.1515/libri-2017-0105
Kang, B. (2021). How the COVID-19 pandemic is reshaping the education service. *The Future of Service Post-COVID-19 Pandemic, Volume 1: Rapid Adoption of Digital Service Technology*, 15–36. https://doi.org/10.1007/978-981-33-4126-5_2
Klingenberg, S., Jørgensen, M. L. M., Dandanell, G., Skriver, K., Mottelson, A., & Makransky, G. (2020). Investigating the effect of teaching as a generative learning strategy when learning through desktop and immersive VR: A media and methods experiment. *British Journal of Educational Technology*, *51*(6), 2115–2138. https://doi.org/10.1111/bjet.13029
Kumar, R. (2025). Bibliometric analysis: comprehensive insights into tools, techniques, applications, and solutions for research excellence. *Spectrum of Engineering and Management Sciences*, *3*(1), 45–62. https://doi.org/10.31181/sems31202535k
Moshinski, V., Pozniakovska, N., Mikluha, O., & Voitko, M. (2021). Modern education technologies: 21st century trends and challenges. *SHS Web of Conferences*, *104*, 3009. https://doi.org/10.1051/shsconf/202110403009
Nurhas, I., Aditya, B. R., Jacob, D. W., & Pawlowski, J. M. (2022). Understanding the challenges of rapid digital transformation: the case of COVID-19 pandemic in higher education. *Behaviour & Information Technology*, *41*(13), 2924–2940. https://doi.org/10.1080/0144929X.2021.1962977
Pellas, N., Mystakidis, S., & Kazanidis, I. (2021). Immersive virtual reality in K-12 and higher education: A systematic review of the last decade scientific literature. *Virtual Reality*, *25*(3), 835–861. https://doi.org/10.1007/s10055-020-00489-9
Prayogi, S., & Verawati, N. N. S. P. (2024). Physics learning technology for sustainable development goals (sdgs): a literature study. *International Journal of Ethnoscience and Technology in Education*, *1*(2), 155–191. https://doi.org/10.33394/ijete.v1i2.12316
Rojas-Sánchez, M. A., Palos-Sánchez, P. R., & Folgado-Fernández, J. A. (2023). Systematic literature review and bibliometric analysis on virtual reality and education. *Education and Information Technologies*, *28*(1), 155–192. https://doi.org/10.1007/S10639-022-11167-5
Rubio-Tamayo, J. L., Gertrudix Barrio, M., & García García, F. (2017). Immersive environments and virtual reality: Systematic review and advances in communication, interaction and simulation. *Multimodal Technologies and Interaction*, *1*(4), 21. https://doi.org/10.3390/mti1040021
Safitri, A. I., & Mubarok, H. (2024). How the evolution and track of several digital technologies in science education? *JPPS (Jurnal Penelitian Pendidikan Sains)*, 113–128. https://doi.org/10.26740/jpps.v13n2.p113-128
Salihu, A., & Sabitu, A. (2024). Impact of virtual reality instruction on secondary school students' conceptual understanding of physics concepts in Dutsin-Ma, Katsina State Nigeria. *Issues and Ideas in Education*, *12*(2), 14–18. https://doi.org/10.15415/iie.2024.122002
Sarkis-Onofre, R., Catalá-López, F., Aromataris, E., & Lockwood, C. (2021). How to properly use the PRISMA Statement. *Systematic Reviews*, *10*(1), 117. https://doi.org/10.1186/s13643-021-01671-z
Sasikumar, N., Ramnath, R., & Mahendraprabu, M. (2022). Augmented reality based instructional approaches to enhance understanding abstract concepts of physics among higher secondary students. *American Journal of Educational Research*, *10*(10), 618–623. https://doi.org/10.12691/education-10-10-5
Selçuk, A. A. (2019). A guide for systematic reviews: PRISMA. *Turkish Archives of Otorhinolaryngology*,

57(1), 57. https://doi.org/10.5152/tao.2019.4058

Suhail, N., Bahroun, Z., & Ahmed, V. (2024). Augmented reality in engineering education: enhancing learning and application. *Frontiers in Virtual Reality*, *5*, 1461145. https://doi.org/10.3389/frvir.2024.1461145

Suprapto, N., Hidaayatullaah, H. N., Hariyono, E., Safitri, A. I., & Fang-Ying, Y. (2025). Analysing metadata insights: The role of eye tracking technology in advancing sports science. *TEM Journal*, *14*(3), 2676. https://doi.org/10.18421/TEM143-69

Tahamtan, I., Safipour Afshar, A., & Ahamdzadeh, K. (2016). Factors affecting number of citations: a comprehensive review of the literature. *Scientometrics*, *107*, 1195–1225. https://doi.org/10.1007/s11192-016-1889-2

Taqwa, M. R. A., & Panya, N. (2026). A bibliometric analysis of communication skills among social sciences students in higher education. *Priviet Social Sciences Journal*, *6*(1), 344–357. https://doi.org/10.55942/pssj.v6i1.719

Tarng, W., & Pei, M.-C. (2023). Application of virtual reality in learning quantum mechanics. *Applied Sciences*, *13*(19), 10618. https://doi.org/10.3390/app131910618

Tomaszewski, R. (2023). Visibility, impact, and applications of bibliometric software tools through citation analysis. *Scientometrics*, *128*(7), 4007–4028. https://doi.org/10.1007/s11192-023-04725-2

Wang, Y., Zhang, L., & Pang, M. (2025). Virtual experiments in physics education: a systematic literature review. *Research in Science & Technological Education*, *43*(2), 633–655. https://doi.org/10.1080/02635143.2024.2327995

Wu, A., & Ye, Y. (2021). Bibliometric analysis on bibliometric-based ontology research. *Science & Technology Libraries*, *40*(4), 435–453. https://doi.org/10.1080/0194262X.2021.1920555

Zou, Y., Kuek, F., Feng, W., & Cheng, X. (2025). Digital learning in the 21st century: trends, challenges, and innovations in technology integration. *Frontiers in Education*, *10*, 1562391. https://doi.org/10.3389/frvir.2024.1461145

Author (s):

*Afaurina Indriana Safitri (corresponding author)
Department of Physics, Faculty of Mathematics and Natural Science,
State University of Surabaya, Indonesia
Email: afaurinaindriana.20007@mhs.unesa.ac.id

Irsyad Yusuf Santoso
Master Program of Science Education, Faculty of Mathematics and Natural Science,
Universitas Negeri Surabaya, Indonesia
E-mail: 24030795020@mhs.unesa.ac.id

Cahyo Febri Wijaksono
Master in Research and Innovation in Higher Education, Faculty of Management and Business,
Tampere University, Finland
Email: cahyo.wijaksono@tuni.fi