Vol 14(2) (2025): 152-173
DOI: http://dx.doi.org/10.24235/sc.educatia.v14i2.24343

SCIENTIAE EDUCATIA: JURNAL PENDIDIKAN SAINS

http://www.syekhnurjati.ac.id/jurnal/index.php/sceducatia

Mapping Research on Immersive Learning Technologies in Science Education: A Bibliometric Analysis of VR–AR–MR Studies

Ahmad Syaiful Anwar[a*], Annastasya Syafitri[b], Dwi Astuti[c], Slamet Suyanto[d]

[a,b,c] Master of Science Program in Biology Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Indonesia
[d] Department of Biology Education, Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Indonesia

[*]Corresponding author: Jl. Kolombo No.1 Karang Malang, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55281. E-mail addresses: ahmadsyaiful.2025@student.uny.ac.id

a r t i c l e i n f o

Article history:
Received: 20 April 2026
Received in revised form: 06 May 2026
Accepted: 15 May 2026
Available online: 22 May 2026

Keywords:
Augmented reality
Immersive learning
Mixed reality
Science education
Virtual reality

a b s t r a c t

Despite the growing prominence of immersive technologies in educational contexts, a comprehensive bibliometric examination of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) within science education remains notably underrepresented in the literature. This study addresses that gap by conducting a quantitative bibliometric analysis to systematically map the broad landscape of immersive learning research in science education. Data were retrieved from the Scopus database and filtered in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, yielding a final corpus of 188 articles for analysis. Bibliometric processing and visualization were performed using Biblioshiny software. The findings reveal that immersive learning research has transitioned from an initiation phase to a period of exponential growth, particularly between 2020 and 2025. Virtual Reality emerged as the dominant technology within this domain, with Augmented Reality and science education serving as primary enablers of interactive learning environments. Prominent keywords, including students, education, and e-learning, collectively underscore a sustained research focus on enhancing conceptual understanding, learner engagement, and overall learning experiences. Geographically, scholarly output is heavily concentrated in the United States, Germany, and China, a pattern attributable to the concentration of immersive technology developers, differential research funding structures, policy orientations, and national education priorities. Notably, the relatively modest international collaboration rate of 22.34% signals considerable untapped potential for cross-national research partnerships. These findings collectively offer a strategic roadmap for advancing innovation at the intersection of immersive technology and pedagogy, while underscoring the imperative for strengthened cross-institutional and international scholarly collaboration.

1. Introduction

The human learning process has historically been grounded in the transmission of knowledge through oral narratives, experiential storytelling, and direct intergenerational practices (Urban, 2025). This foundational paradigm, however, underwent a profound transformation with the advent of writing, which facilitated the development of texts, manuscripts, and books as the predominant media for knowledge dissemination. Written media significantly expanded both the scope and scale of information transfer across time and geography. Nevertheless, the progressive reliance on textual forms of learning gradually reoriented educational practice toward symbolic and theoretical representations, at times diminishing the immediacy and authenticity of real-world experiential context (Mystakidis & Lympouridis, 2023). This condition underscored the enduring necessity of authentic, experience-based learning as a complement to text-mediated instruction.

The imperative for experiential learning was most influentially articulated by Kolb, whose experiential learning theory places lived experience at the center of knowledge creation, conceptualizing knowledge as the product of the integrated transformation of information acquisition and experiential engagement (de Figueiredo et al., 2022; Morris, 2020). In recent decades, rapid advances in digital technology have once again created compelling opportunities to bridge the longstanding gap between textual knowledge and real-world experience through the emergence of immersive learning. Immersive learning leverages technology to construct simulated environments in which learners perceive themselves as physically present, thereby enabling meaningful and embodied interactions with virtual representations of real-world contexts (Lin et al., 2024). This approach has garnered considerable scholarly and pedagogical attention in recent years, owing principally to its inherently learner-centered orientation and its strong theoretical alignment with the constructivist principles advanced by Jean Piaget, wherein learners actively construct understanding through experiential engagement and sensory stimulation rather than passive information reception (Muzata et al., 2024). Furthermore, immersive learning has been empirically demonstrated to enhance learner participation and strengthen student engagement, particularly among Generation Z learners, who exhibit a pronounced affinity for digital and internet-mediated environments (Kuhail et al., 2022).

These characteristics collectively affirm the substantial potential of immersive learning as a subject of continued scholarly investigation and pedagogical development. Its relevance is especially pronounced within the domain of science education, wherein scientific content is frequently perceived by learners as inherently abstract and cognitively demanding. Learning in science becomes considerably more meaningful when students are afforded the opportunity to interact directly with the phenomena under investigation (Setiawan & Winarno, 2024). In circumstances where physical interaction is not practically feasible, immersive learning provides an alternative pathway by rendering complex scientific phenomena in three-dimensional (3D) form within fully navigable virtual environments (Mystakidis & Lympouridis, 2023). Critically, the immersive quality of such environments is not solely derived from sensory stimulation but is further reinforced through the integration of compelling and contextually meaningful narratives (Agrawal et al., 2020). Taken together, these attributes position immersive learning as a highly promising and pedagogically valuable approach within the broader landscape of science education.

Research on immersive learning in science education has expanded considerably in recent years, generating a diverse and rapidly growing body of scholarly contributions. Previous studies have predominantly concentrated on the design, development, and evaluation of individual immersive technologies in isolation. For instance, Muslima (2025) developed VR-based instructional media for teaching cell organelles, Brahmana et al. (2025) examined the development of AR-based learning media for the excretory system, and Veer et al. (2022) investigated the effectiveness of MR as an engaging alternative learning medium. Similarly, prior bibliometric investigations have tended to map publication trends within a single technology domain; notable examples include the analysis of AR-related publication growth in education by Harnal (2024), the examination of upward VR publication trends in science education by Setiawan and Winarno (2025), and the bibliometric review of VR and AR during the period 2018–2020 by Zhao et al. (2023). A critical limitation of these approaches, however, lies in their fragmented treatment of immersive technologies, which precludes a comprehensive and comparative understanding of the collective development of VR, AR, and MR within a unified analytical framework. To address this gap, the present study offers a novel perspective by conducting an integrated bibliometric mapping that simultaneously encompasses VR, AR, and MR, thereby enabling a holistic examination of their scholarly development, thematic trajectories, and prospective directions for future implementation in science education.

Accordingly, this study aims to address the identified gap through a systematic bibliometric mapping analysis focusing on immersive VR, AR, and MR technologies within the context of science education. Through this analytical approach, the study seeks to construct a comprehensive research productivity map and identify the dominant thematic clusters characterizing the literature on the application of VR, AR, and MR in science education. Specifically, this study is guided by the following research questions (RQ):

RQ1: What are the prevailing trends in research productivity — as measured by annual publication output — and who are the most influential authors, journals, institutions, and countries driving scholarly advancement in this field?

RQ2: What are the principal research themes and trending keywords (hotspots) within the corpus, and how has the thematic evolution of immersive learning research in science education developed over the study period?

RQ3: What is the structural configuration of the collaboration network among researchers and countries engaged in immersive VR, AR, and MR research in science education?

2. Method

This study employed a bibliometric mapping analysis as its primary research methodology. Bibliometric analysis constitutes an effective and widely recognized approach for summarizing and synthesizing large bodies of scholarly literature (Donthu et al., 2021). The procedural framework of this method comprises four sequential steps: (1) determining the purpose and scope of the study, (2) selecting appropriate analytical techniques, (3) collecting relevant data, and (4) conducting the analysis and reporting the findings. The bibliometric analysis in this study was delimited based on two principal criteria: the publication year range and the keywords employed.

Data were retrieved through systematic electronic search and retrieval methods conducted on November 14, 2025. Article data were initially searched within the Scopus international database. Scopus was selected as the primary data source owing to its extensive coverage of research publications across multiple disciplines and its well-established credibility as a leading research indexing platform.

The keyword search was configured to encompass the title, abstract, and keywords fields. The search string applied in this study was as follows: TITLE-ABS-KEY ("immersive learning" OR "Virtual Reality" OR "Augmented Reality" OR "Mixed Reality") AND ("science education"). The inclusion criteria applied in this study were: (1) the article must contain at least one of the designated keywords within its title, abstract, or keywords; (2) the publication period was restricted to 2015–2025; and (3) the article must be written in English. The exclusion criteria were as follows: (1) document types other than original research articles, including review articles, conference papers, and notes; (2) articles published in languages other than English; and (3) articles that are not openly accessible.

The application of these search parameters yielded a total of 255 publications in the Scopus database, comprising 192 original articles, 32 review articles, 21 conference papers, 3 errata, and 3 notes. For the purposes of this study, only the 192 original articles were retained for further processing. Of these, 2 articles were subsequently excluded as they remained in press at the time of data collection, and an additional 2 articles were excluded due to their publication in languages other than English. Consequently, a final corpus of 188 articles was obtained and subjected to bibliometric analysis. The literature selection process is systematically presented in Figure 1.

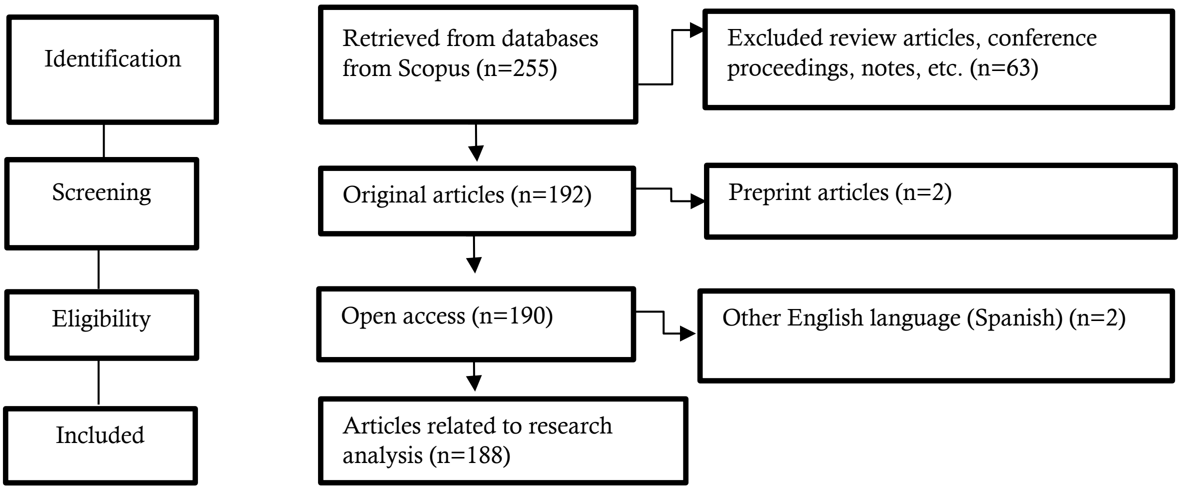

Figure 1. PRISMA diagram of bibliometric research

Data were retrieved from the Scopus database in Research Information Systems (RIS) format, encompassing citation metadata, bibliographic information, abstracts, and author-assigned keywords. The retrieved data were subsequently processed and visualized using the Biblioshiny platform, which was selected owing to its comprehensive analytical capabilities and its status as one of the most widely adopted tools for bibliometric analysis in the contemporary scholarly literature (Ullah et al., 2022).

3. Result and Discussion

Following the systematic data selection process delineated in the methodology, a final corpus of 188 articles was subjected to bibliometric analysis using Biblioshiny software. This preliminary analytical stage yielded a comprehensive statistical overview of the research corpus, providing foundational insight into the structural characteristics of the reviewed literature. A summary of the key descriptive statistics derived from the 188 documents is presented in Table 1, encompassing the research time frame, total document volume, average citations per document, and collaboration metrics. These descriptive parameters collectively serve as the empirical foundation upon which the subsequent in-depth thematic and structural analyses are grounded.

Table 1. Main information about data corpus

Description	Results
Main Information About Data	
Timespan	2015:2025
Sources (Journals, Books, etc)	115
Documents	188
Annual Growth Rate %	33.51
Average Document Age	2.74
Average citations per document	18.24
References	1624
Document Contents	
Keywords Plus (ID)	562
Author's Keywords (DE)	586
Authors	
Authors	679
Authors of single-authored documents	15
Authors Collaboration	
Single-authored documents	15
Co-Authors per Document	4.02
International co-authorships %	22.3
Document Types	
Article	188

Research productivity trends (number of publications per year), authors, journals, and most influential institutions (RQ1)

A descriptive analysis of the 188 articles included provides an overview of the research landscape, summarized in Table 1. The analysis of productivity and impact focuses on annual trends, sources (journals), authors, and affiliations (institutions and countries).

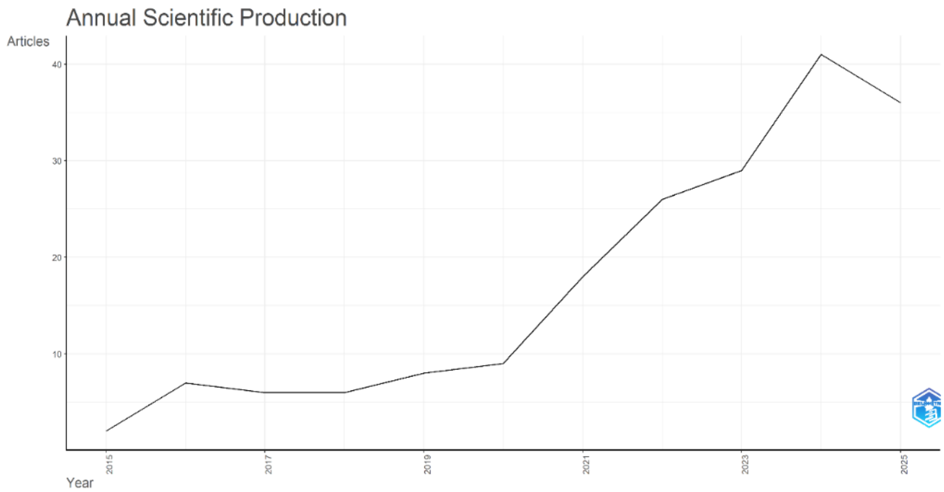

Figure 2. Annual scientific production

Analysis of annual scientific production reveals that research on immersive learning in science education, particularly concerning the application of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) within the open-access corpus, represents a relatively nascent yet rapidly expanding field of scholarly inquiry. As illustrated in Figure 2, of the 188 articles analyzed, the earliest publications were identified in 2015, comprising 2 articles. A subsequent increase was observed in 2016, with 7 articles published, followed by a moderate decline during 2017 and 2018, with 6 articles recorded in each respective year. Publication output began to demonstrate a steady and consistent upward trajectory from 2019 onward. Most notably, the most significant finding of this analysis is the exponential surge in scholarly output observed over the most recent five-year period, with annual publication counts recorded as follows: 9 articles in 2020, 18 articles in 2021, 26 articles in 2022, 29 articles in 2023, 41 articles in 2024, and 36 articles in 2025 — the latter representing publications retrieved up to November 22, 2025.

The analysis of annual scientific production, as presented in Figure 2 and Table 2, demonstrates that research in the field of immersive learning has undergone substantial and progressive development over the study period. The comparatively modest publication output recorded in 2015 is indicative of the early pioneering phase of this research domain, characterized by limited but foundational scholarly contributions. In contrast, the pronounced surge in publication output observed from 2020 onward signifies that immersive learning research within educational contexts has rapidly ascended to become a prominent focus of the global academic community. This accelerating trajectory not only underscores the growing relevance and timeliness of this field but also affirms that the domain remains far from saturation, instead exhibiting the characteristics of a rapidly expanding and dynamically evolving area of scholarly inquiry. Consequently, bibliometric analysis emerges as an indispensable methodological tool for systematically mapping the key contributors, dominant themes, and structural dynamics that are collectively driving this remarkable growth in immersive learning research.

Table 2. Annual scientific production

Year	Articles
2015	2
2016	7
2017	6
2018	6
2019	8
2020	9
2021	18
2022	26
2023	29
2024	41
2025	36

Figure 3 illustrates the temporal distribution of author productivity, providing a comprehensive visualization of individual scholarly contributions to immersive learning research in science education over the study period. The author production over time graph depicts the dynamics of researcher productivity through a bubble plot representation, wherein each data point corresponds to a specific author-year combination. The size of each point reflects the volume of publications contributed in a given year (N Articles), while the color intensity indicates the corresponding annual citation rate (TC per Year), collectively enabling a nuanced assessment of both quantitative output and scholarly impact over time.

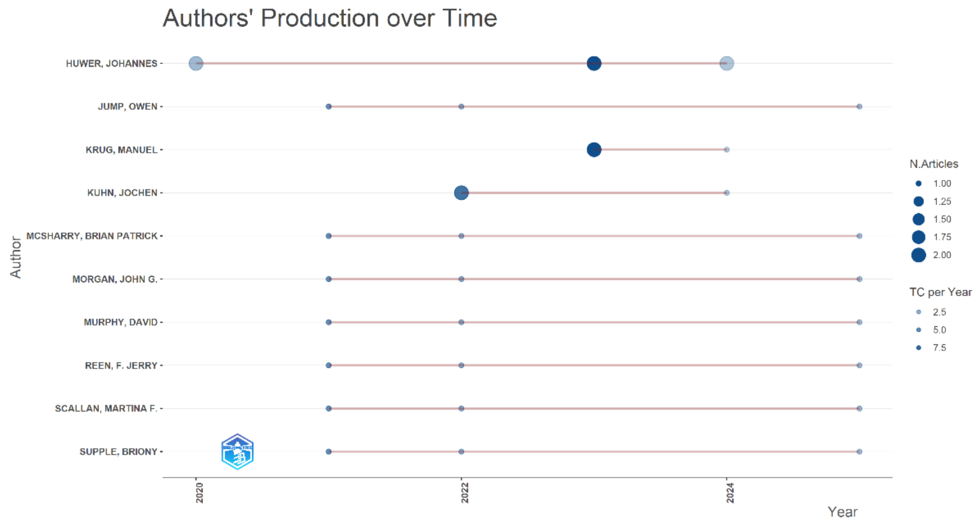

Figure 3. Author's production over time

The visualization reveals that Huwer, J. exhibits the most consistent and prominent publication pattern among all identified authors, with contributions spanning multiple years and notably larger point sizes, indicative of a substantially higher cumulative output relative to other researchers in this domain. This sustained productivity positions Huwer, J. as the most influential and prolific contributor to immersive learning research in science education within the analyzed corpus. Additional active contributors include Krug, M. and Kuhn, J., both of whom demonstrate concentrated publication activity within specific temporal intervals, although their overall volume of scholarly output remains comparatively lower than that of Huwer, J. Collectively, these patterns suggest the emergence of a core group of highly productive researchers whose sustained contributions have been instrumental in shaping the intellectual trajectory of immersive learning research in science education.

The remaining authors identified in the corpus — including Jump, O.; McSharry, B.P.; Morgan, J.G.; Murphy, D.; Reen, F.J.; Scallan, M.F.; and Supple, B. — demonstrate comparatively limited publication patterns, with contributions restricted to one or a small number of articles within discrete temporal intervals. This distribution indicates that scholarly contributions in the field of immersive learning in science education tend to be markedly concentrated among a relatively small cohort of core authors, while the majority of researchers assume episodic or peripheral roles in the broader production of knowledge within this domain.

Collectively, the temporal production graph presented in Figure 3 illustrates that the development of immersive learning scholarship in science education is propelled by a dual dynamic: a nucleus of highly prolific and consistently productive authors, complemented by a broader constellation of researchers who contribute sporadically across the study period. These findings are consistent with the well-established Lotka's Law of scientific productivity, which posits that a disproportionately small number of authors account for the majority of scholarly output within any given research domain. Accordingly, the observed disparity in author productivity underscores the pivotal and sustained influence of a select group of core researchers in driving the intellectual advancement and thematic evolution of immersive learning research in science education throughout the analyzed period.

Table 3. Most relevant sources

Sources	Articles
Education Sciences	12
International Journal of Information and Education Technology	8
Education and Information Technologies	5
Information (Switzerland)	4
International Journal of Emerging Technologies in Learning	4
Journal of Science Education and Technology	4
Science Education International	4
Sustainability (Switzerland)	4
Applied Sciences (Switzerland)	3
Eurasia Journal of Mathematics, Science and Technology Education	3

Table 3 presents the most relevant sources identified in this bibliometric analysis, highlighting the journals that have contributed most significantly to the dissemination of immersive learning research in science education. The analysis of publication sources reveals that Education Sciences is the most dominant outlet, having published a total of 12 articles, thereby establishing itself as the leading platform for the dissemination of immersive learning research within educational contexts. This prominent position reflects the journal's central role as a primary venue through which researchers publish findings pertaining to digital learning innovation and educational technology development. The International Journal of Information and Education Technology follows with 8 articles, affirming its significant and sustained contribution as a journal that actively accommodates scholarly work at the intersection of information technology and educational practice. Education and Information Technologies contributed 5 articles, reflecting its consistent facilitation of academic discourse on artificial intelligence-driven learning technologies and digital educational systems.

Beyond these three leading sources, several additional journals have made noteworthy contributions, albeit at more moderate levels of output. Information (Switzerland), the International Journal of Emerging Technologies in Learning, the Journal of Science Education and Technology, Science Education International, and Sustainability (Switzerland) each contributed 4 articles, collectively indicating that immersive learning research in science education has developed in a distinctly multidisciplinary manner, extending beyond purely pedagogical innovation to encompass dimensions of sustainability and global science education. Applied Sciences (Switzerland) and the Eurasia Journal of Mathematics, Science and Technology Education, each contributing 3 articles, further corroborate the broad dissemination of immersive learning scholarship across reputable international journals at the convergence of education, technology, and science. Collectively, these findings demonstrate that immersive learning research has established a robust and well-distributed publication foundation across multiple leading international journals, reflecting both the interdisciplinary breadth and the growing mainstream recognition of this field. Table 4 presents the most relevant affiliations contributing to immersive learning research in science education, highlighting the institutions that have played a pivotal role in advancing scholarly output within this domain.

Table 4. Most relevant affiliations

Affiliation	Articles
University College Cork	16
Saarland University	6
Beijing Normal University	5
Weingarten University of Education	5
Volodymyr Hnatiuk National Pedagogical University of Ternopil	5
University of Münster	5
University of Wisconsin-Madison	5
University of Konstanz	5
Christian-Albrechts University of Kiel	4
International Islamic University Malaysia	4

The analysis of the most relevant affiliations reveals that University College Cork stands as the leading institution in terms of scholarly contributions to immersive learning research in science education, having produced a total of 16 publications. This dominant position affirms the university's established role as a prominent research center actively advancing VR-, AR-, and MR-based pedagogical approaches aimed at enhancing conceptual understanding in science education. Substantial contributions were additionally recorded from several other leading institutions, including Universität des Saarlandes with 6 publications, followed by Beijing Normal University, Pädagogische Hochschule Weingarten, Ternopil Volodymyr Hnatiuk National Pedagogical University, University of Münster, University of Wisconsin–Madison, and Universität Konstanz, each contributing 5 publications. Christian-Albrechts-Universität zu Kiel and International Islamic University Malaysia each recorded 4 publications, further reflecting the breadth of institutional engagement in this field.

Table 5. Countries scientific production

Country	Frequency
USA	55
Germany	50
China	48
Indonesia	36
Australia	25
Malaysia	24
Ireland	20
Turkey	18
UK	17
Greece	14

The diversity of contributing institutions underscores the increasingly global nature of immersive learning research in science education. The representation of institutions spanning Europe, Asia, and North America collectively demonstrates that scholarly interest in this domain has expanded well beyond regional boundaries, supported by growing cross-national research collaboration. Collectively, these findings indicate that the adoption of immersive technologies in science education is primarily driven by institutions with a sustained and strategic commitment to pedagogical innovation and the advancement of technology-enhanced learning experiences. Table 5 presents the scientific production by country, revealing the geographical distribution of scholarly contributions to immersive learning research in science education and highlighting the nations that have most significantly shaped this field.

Publication productivity rates by country, illustrating global contributions to research on immersive learning in science education. The United States emerges as the country with the highest publication frequency, followed by Germany, China, and Indonesia. The dominance of these countries indicates that immersive learning research such as the use of virtual reality, augmented reality, and mixed reality has developed rapidly in regions with strong research capacity and a focus on educational innovation. The involvement of other countries such as Australia, Malaysia, Ireland, Turkey, the United Kingdom, and Greece shows that research on immersive learning is inclusive and increasingly global. Overall, this distribution reflects growing international attention to the use of immersive learning technology to improve the quality of science learning through more interactive, contextual, and exploration-based learning experiences.

The first research question (RQ1) aims to identify productivity trends, authors, and the most influential journals or institutions in the field of immersive learning, particularly in science education. The findings show that in the period 2015-2019, research on immersive learning was still categorized as an underdeveloped niche. This " " condition may have been influenced by educational priorities during that period, which did not place the use of technology as a main focus. As a result, research funding allocation was still limited, and the adoption of new technology for science education was slow (Setiawan & Winarno, 2024).

Conversely, since 2020, there has been an exponential surge in publications related to the use of immersive learning in education. This increase shows that immersive technology has encouraged the development of theories, methods, and interactions that offer richer and more engaging 3D experiences. Technological advances in the current era mean that the potential for immersive learning can be projected to become more sophisticated, accessible, and flexible for adaptation in pedagogical practice (Ahmadi & Gilardi, 2024). Additionally, this period coincided with the COVID-19 pandemic, which forced countries to adapt to online learning on a massive scale (Hollister et al., 2022).

Bibliometric analysis shows that Huwer, Johannes is the most prolific author in immersive learning research over the past 10 years (2015-2025). The frequency of repeated appearances indicates that Huwer, Johannes has deep expertise and plays a key role as a researcher who is often referenced by other researchers. Consistent publication productivity also shows that the author tends to be involved in a broad collaborative network, placing him in a central position in the scientific collaboration structure. By identifying the most prolific authors in a field, mapping the patterns of scientific development and the direction of immersive learning research in science education can be done more accurately.

The results of the analysis of the most relevant sources show that the Education Sciences journal is the most dominant publication source with a total of 12 articles related to immersive learning. This dominance is in line with the findings (Gusteti et al., 2025) which state that Education Science is one of the most active journals in publishing articles related to immersive learning and augmented reality. Additionally, significant contributions were also seen in the International Journal of Information and Education Technology and Education and Information Technologies. The existence of these three journals as core sources indicates the presence of a stable scientific forum for developing or critiquing the immersive learning approach.

Furthermore, the results of the most relevant affiliations analysis show that University College Cork is the institution with the largest contribution to research related to immersive learning in science education, with a total of 16 publications. This dominance confirms the university's position as a research center that actively develops VR, AR, and MR-based learning approaches for science learning. Further contributions come from several other leading institutions. These findings collectively indicate that immersive learning research has a strong and evenly distributed publication base.

The United States emerged as the country with the highest publication frequency, followed by Germany, China, and Indonesia. However, when these findings are compared to a study (Lampropoulos, 2025) that mapped global trends in the combination of AI with AR and VR, a different pattern emerges. In that study, China ranked first, followed by the United States. This difference indicates that a country's dominance in publications also depends on its research domain. Furthermore, the dominance of these two countries in AR/VR technology can be understood through their highly aggressive national policies in promoting AI development. The difference is that China's expansion focus is more directed towards the digital technology industry (Hine & Floridi, 2024). Thus, the United States is considered to be more focused on education-based research within a pedagogical framework that utilizes immersive technology.

Main research themes, trending keywords (hotspots), and thematic evolution (RQ2)

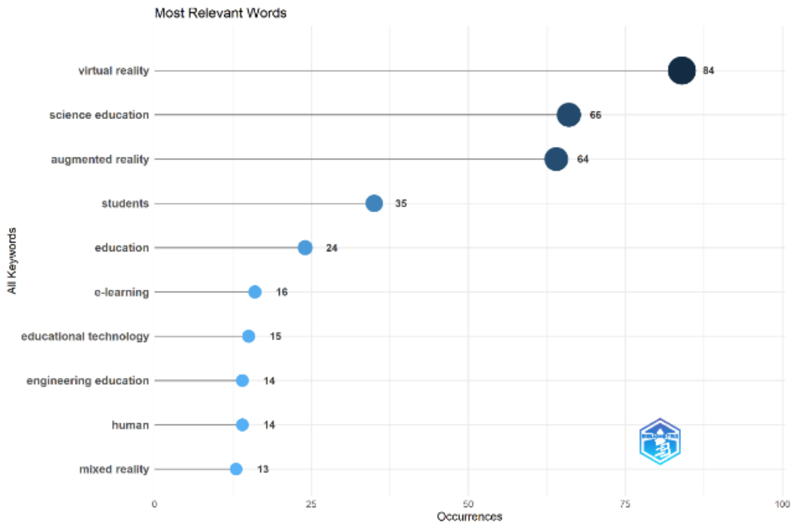

Figure 4. Most relevant word

Figure 4 presents the most relevant words identified through bibliometric analysis, reflecting the predominant themes and conceptual focus areas that have characterized immersive learning research in science education over the past decade. The three most frequently occurring keywords are virtual reality (VR), science education, and augmented reality (AR), recorded at exceptionally high frequencies of 84, 66, and 64 occurrences, respectively. The pronounced dominance of these three terms collectively confirms that immersive learning research in science education is fundamentally anchored in the application of immersive technologies as primary pedagogical media, with VR and AR serving as the central technological drivers of scholarly inquiry in this domain.

The high occurrence frequency of terms such as students, education, and e-learning further indicates that immersive technologies are not conceptualized as standalone tools but are instead systematically positioned within broader pedagogical frameworks aimed at enhancing learning experiences, fostering active student participation, and deepening conceptual understanding in science education. This pattern underscores the inherently learner-centered orientation of immersive learning research, wherein technological innovation is consistently framed in relation to its educational outcomes and pedagogical implications. Furthermore, the emergence of terms including educational technology, engineering education, and mixed reality signals a discernible shift in research trajectories toward cross-disciplinary integration, particularly at the nexus of science, engineering, and digital technology. This trend reflects the growing recognition that immersive learning environments possess significant potential to bridge disciplinary boundaries and catalyze innovative approaches to science and technology education in the 21st century.

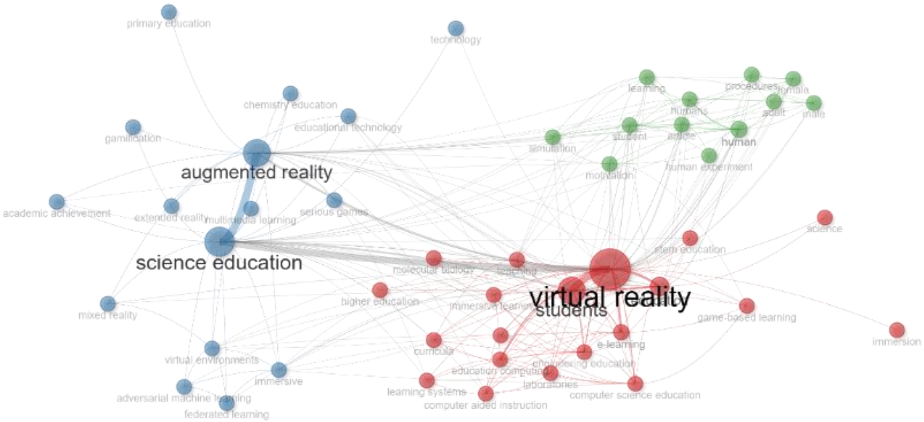

Figure 5. Co-occurrence network

Figure 5 presents the co-occurrence network of keywords, visually mapping the intellectual structure and thematic interconnections that underpin immersive learning research in science education over the study period. This keyword network shows that virtual reality is the strongest hub in immersive learning research in science education. The red cluster surrounding it indicates VR's proximity to topics such as students, immersive learning, STEM education, e-learning, and computer science education, signifying that VR is positioned as a core technology for creating deep, interactive, and contextual learning experiences. Meanwhile, the blue cluster shows the role of augmented reality and science education as another important node, connected to concepts such as serious games, multimedia learning, and extended reality. This indicates that the immersive approach does not only rely on VR, but is developing as a technology ecosystem that supports the visualization of abstract scientific concepts. The smaller green cluster, related to learning, motivation, and human experiments, shows the research orientation towards the behavioral and cognitive aspects of learners. Figure 6 presents the density co-occurrence network, highlighting the concentration of keyword clusters and identifying the most intensively researched thematic areas within immersive learning in science education.

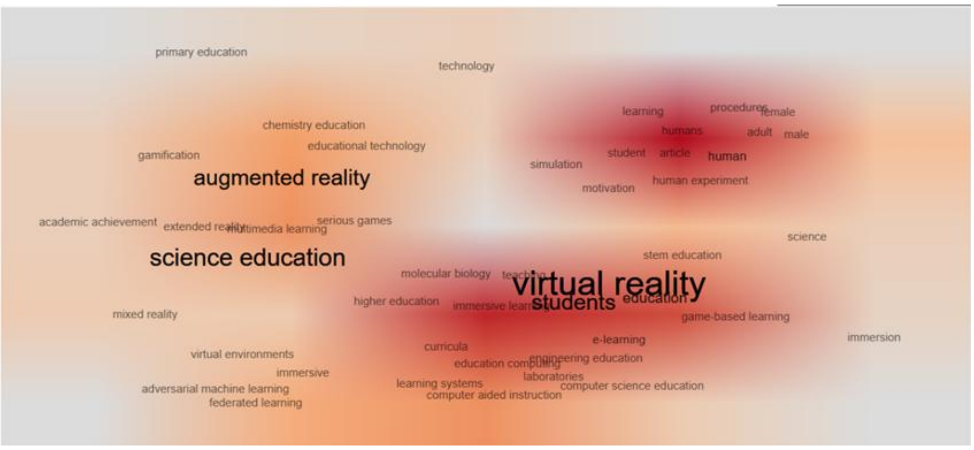

Figure 6. Density co-occurrence network

The density co-occurrence network presented in Figure 6 reveals that the terms virtual reality and students constitute the intellectual core of immersive learning research in science education, as evidenced by the highest concentration of warm-colored regions centered around these two nodes. The pronounced intensity of red coloration in this zone is indicative of the exceptionally high frequency of co-occurrence between these terms, reflecting the dominant research focus on VR as the primary medium for immersive learning in science education. Closely situated within this high-density zone are terms including STEM education, e-learning, game-based learning, and computer science education, collectively suggesting that immersive technologies are increasingly positioned as transformative tools for deepening conceptual understanding in science through interactive and simulation-based learning experiences.

In the adjacent warm-colored region, the co-occurrence of science education and augmented reality demonstrates a strong and well-established thematic connection between AR-based approaches and science instruction, particularly in relation to sub-themes such as multimedia learning, serious games, and extended reality. This cluster underscores the complementary role of AR in enriching the pedagogical landscape of science education alongside VR. In contrast, the peripheral cluster characterized by lighter pink coloration on the right side of the network, encompassing terms such as human, learning, motivation, and human experiment, reflects a distinct psychopedagogical research orientation, directed toward investigating how immersive learning experiences influence students' motivational states, cognitive engagement, and broader learning processes. Collectively, these density patterns affirm the multidimensional thematic structure of immersive learning research and highlight the convergence of technological, pedagogical, and psychological dimensions within this rapidly evolving field.

Figure 7 presents the thematic map, categorizing research themes into four quadrants based on their degree of development and relevance, thereby revealing the structural dynamics of immersive learning research in science education. The thematic map shows the conceptual position of various keywords in immersive learning research in science education based on relevance (centrality) and development (density). Virtual reality, students, and education emerge as basic themes with very high centrality but relatively low density, indicating that these three are the main foundations that support immersive learning research, although their development still has potential for expansion. Meanwhile, science education, augmented reality, and educational technology are in the quadrant with high centrality and moderate density, indicating that these themes serve as important connecting nodes in the research ecosystem and are stable topics in the discourse of immersive technology-based science education.

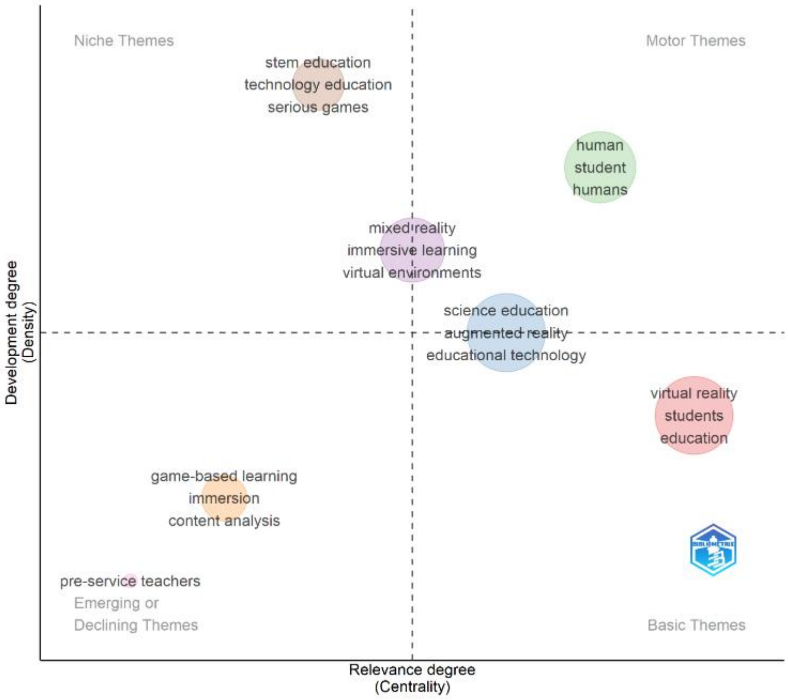

Figure 7. Thematic map

On the other hand, themes such as mixed reality, immersive learning, and virtual environments are in the transition zone with moderate centrality and density. This position indicates that cross-platform immersive technology is developing as a research area that leads to the integration of new concepts in science learning. The human, student, and humans clusters are in the motor themes quadrant, indicating a strong research focus on cognitive aspects, learning experiences, and human-technology interactions, which are the main drivers of immersive learning innovation. Themes such as game-based learning, immersion, and bibliometric analysis are in the emerging or declining quadrant, indicating that although their relevance is still low, these areas may develop further as game-based approaches and bibliometric analysis become more prevalent in understanding the effectiveness of immersive learning in science education.

The second research question (RQ2) concerns the main research themes, trending keywords (hotspots), and thematic evolution. Bibliometric results show that the immersive learning research ecosystem in science education is dominated by three main thematic axes, namely virtual reality, science education, and augmented reality. These three not only appear as the keywords with the highest frequency but also form the most central thematic structure in the co-occurrence network (Lampropoulos & Evangelidis, 2025). This pattern confirms that the development of science learning theory and practice over the past decade has been greatly influenced by the use of immersive technology as the primary medium for enhancing learning experiences (Avila-Garzon et al., 2021).

Structurally, the co-occurrence map reveals that virtual reality is the strongest thematic node, with extensive connections to the themes of students, immersive learning, STEM education, and game-based learning (Nawaz et al., 2025). This shows that VR is positioned as a technology capable of transforming the dynamics of learning through interactive simulation and visualization. Meanwhile, augmented reality forms an independent cluster connected to serious games, extended reality, and multimedia learning, indicating that AR is developing as a pedagogical approach that enriches the interaction between real contexts and digital objects (Pezzino et al., 2025). These findings show that VR and AR do not compete conceptually, but complement each other in the immersive learning ecosystem (Aljabari et al., 2025).

Density analysis confirms that VR and students are research hotspots, with the highest intensity of exploration (Nedeva et al., 2025).Themes related to science education and educational technology have medium density, indicating the stability of research contributions as well as their role as an integrative bridge between immersive technology and formal learning systems. Meanwhile, the emergence of clusters highlighting motivation, human learning, and human experiments shows a shift in focus towards psychopedagogical dimensions, particularly how immersive experiences affect student engagement and cognitive processes (Videira et al., 2025).

The thematic map shows a clearer evolution. The themes of VR, education, and students are in the basic themes quadrant, indicating a strong and expanding conceptual (Avila-Garzon et al., 2021). Conversely, science education, AR, and educational technology serve as motor themes, i.e., themes that drive scientific and methodological innovation in this field (Leung et al., 2023). Meanwhile, mixed reality, virtual environments, and immersive learning are in the emerging themes zone, indicating that MR technology and multi-platform virtual environments are moving towards more systematic integration in science education (Aljabari et al., 2025).

Overall, these results show that global research is not only focused on the development of immersive technologies, but also on how these technologies can mediate cognitive and affective learning processes (Pezzino et al., 2025). The thematic evolution from VR to the AR–MR ecosystem marks a paradigm shift from mere technology adoption to the creation of multisensory, contextual, and learner-centered learning experiences (Lampropoulos & Evangelidis, 2025)

The structure of researcher and country collaboration networks in research on immersive VR, AR, and MR in science education (RQ3)

The Country Scientific Production Map presented in Figure 8 provides a comprehensive geographical representation of global research contributions to immersive learning in science education. This cartographic visualization corroborates the quantitative productivity findings previously documented in Table 5, confirming that the United States, Germany, and China collectively constitute the three most prolific contributing nations in terms of total publication output within this corpus. The geographical concentration of research output in these three countries reflects the confluence of several structural factors, including the high density of immersive technology developers, robust research funding mechanisms, strategic national research policy orientations, and well-established educational technology infrastructures.

Beyond these three dominant contributors, Figure 8 further identifies a number of additional active research centers distributed across multiple regions. In Asia, Indonesia emerges as a noteworthy contributor, followed by Malaysia and Australia in the broader Asia-Pacific region. European contributions are represented by Ireland, Turkey, the United Kingdom, and Greece, reflecting the growing geographical diversification of immersive learning scholarship beyond the dominant research hubs. Collectively, this global distribution underscores the increasingly international character of immersive learning research in science education, while simultaneously highlighting the existing disparities in research output that warrant greater cross-national collaboration and more equitable participation from emerging research economies.

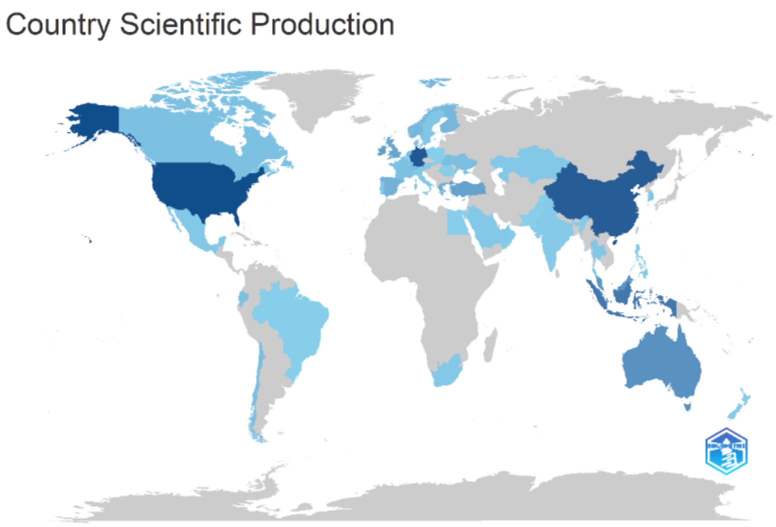

Figure 8. Country scientific production

The country scientific production map presented in Figure 8 serves not merely as a geographical visualization but also as a reflection of the broader social and structural dynamics governing global research activity in immersive learning — particularly concerning the application of VR, AR, and MR in science education. The pronounced concentration of scholarly output in a limited number of key countries, most notably the United States, Germany, and China, underscores the global relevance and growing academic prominence of this research domain. However, this geographical concentration must be considered alongside the relatively modest international collaboration rate of 22.34%, as documented in Table 1, which indicates that there remains considerable and largely untapped potential for the expansion of intercontinental research partnerships in this field.

Strengthening collaborative research networks among existing centers of excellence — spanning researchers across North America, Europe, and Asia — holds significant promise for generating more comprehensive, cross-regional empirical findings and for broadening the generalizability of immersive learning practices in science education. Enhanced international collaboration would not only diversify the geographical and cultural contexts within which VR-, AR-, and MR-based interventions are investigated but would also contribute to the development of more universally applicable pedagogical frameworks capable of informing immersive learning practice at a truly global scale. Accordingly, fostering more inclusive and equitable cross-national research partnerships is identified as a strategic priority for the sustained advancement of this field.

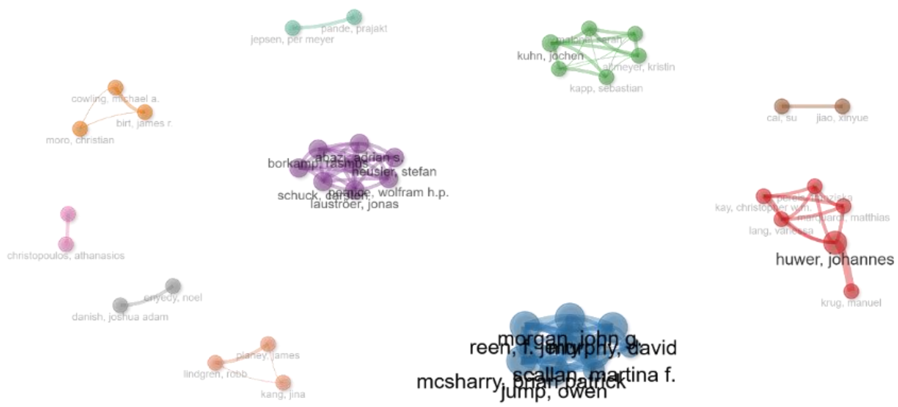

Figure 9. Collaboration network

Figure 9 presents the country collaboration network, visually mapping the patterns of international research partnerships and revealing the degree of scholarly interconnectedness among contributing nations in immersive learning research. The collaboration network map illustrates the structure of relationships between authors in the field of immersive learning research, specifically AR, VR, and MR in science education, where each node represents an author and each color indicates the formation of consistent collaborative clusters. Large clusters with high connectivity, such as the green, red, purple, or blue groups, indicate the existence of productive research communities with strong collaboration intensity. The dense relationship patterns within these clusters show that the authors involved often engage in joint publications, share thematic focuses, or belong to interconnected institutional networks.

Conversely, smaller clusters comprising only two to three authors are indicative of comparatively limited and sporadic collaborative relationships, typically characteristic of independent research endeavors, highly specialized thematic investigations, or transient research partnerships that have not evolved into sustained and broader collaborative networks.

The relatively considerable spatial distance observed between clusters reflects a degree of fragmentation within the scientific community, wherein distinct research groups operate within differentiated thematic focuses or methodological orientations with minimal inter-cluster connectivity. In contrast, clusters positioned in close proximity to one another suggest shared thematic interests and latent potential for cross-cluster collaboration, even in the absence of established publication linkages. This structural pattern underscores the existence of unexplored collaborative opportunities that, if strategically cultivated, could significantly enrich the intellectual diversity and methodological breadth of immersive learning research in science education.

Collectively, the collaboration network map provides a comprehensive overview of the dynamics of knowledge production within this field, systematically identifying the central research groups, the distributional structure of scientific networks, and the prevailing degree of integration or fragmentation characterizing the research community. This structural analysis is of considerable scholarly significance, as it illuminates the mechanisms through which scientific collaboration networks are formed and sustained, while simultaneously identifying strategic pathways through which cross-institutional and cross-national collaboration may be expanded to strengthen and diversify academic contributions to immersive learning research in science education in the years ahead.

The third research question (RQ3) examines the patterns of collaboration networks between researchers and countries in research on immersive learning, including virtual reality, augmented reality, and mixed reality in science education. RQ3 also confirms the findings in RQ2. The results show strong findings in several countries, such as the United States, Germany, and China. The United States emerged as the largest contributor, demonstrating its commitment and excellence in the field of immersive learning. Samala et al., (2025) explain that the United States has strong research infrastructure, supportive funding, and many universities dedicated to technology and information. The use of immersive learning, especially virtual reality, in higher education is widespread in China (Zhuang et al., 2024). Institutions in this context, universities in China, are almost evenly involved in the development and provision of VR-based courses as a leap forward and breakthrough in innovative education and training methodologies. Virtual Reality, as part of immersive learning, has become a priority program for the Chinese government in its national technology development plan, which highlights VR as essential for industrial and educational transformation.

Meanwhile, Germany is a country renowned for its robust infrastructure in cutting-edge VR technology research and innovation. Germany also focuses on the development and application of VR in the context of education (Samala et al., 2025). Germany is also known for its strong vocational education system, with the integration of immersive learning in learning to train technical skills and tacit knowledge (practical knowledge) in a digital environment (Spangenberger et al., 2023). The development of immersive learning teaching in these three countries is not only due to the contribution of universities but is also supported by the development of large industries such as Google, Meta, and Microsoft in the United States, and Huawei and Tercent in China.

The relatively low level of international collaboration, at 22.34%, indicates that there is still a need or considerable room for improvement in inter-country collaborative research. Several analyses of this phenomenon point to the technology gap as a factor, such as differences in infrastructure between countries (Shonfeld et al., 2025). In some countries, it is difficult to conduct cross-country comparative studies due to limited access to devices or files that are incompatible with those of the developing countries (Hou, 2024). Another factor is that immersive learning often involves motion capture, light biometrics, and student interaction data, and some countries have fairly strict regulations on this (Fidas et al., 2021). Funding is also a very important factor, as education research funding often focuses on the domestic priorities of each country (Zhuang et al., 2024). Another factor is the different focus of each country. For example, Germany focuses on its VET, the United States focuses on corporate training and STEM Education , while developing countries focus on basic digital access and literacy. These reasons have led to research on immersive learning being fragmented within domestic boundaries.

However, based on the findings, collaboration is still possible, for example, in the research by AlAli et al., (2025), researchers from Saudi Arabia and Jordan who studied the effectiveness of using augmented reality in science education to enhance student creativity. Collaboration is also demonstrated by (Alhebaishi et al., 2025), a collaborative research between institutions in the United States and Saudi Arabia. This collaboration plays an important role in the development of immersive learning technology and its application in education for the advancement of education and broader international engagement.

This collaboration has expanded the scope of research on immersive learning, improved the quality of education, and reflected the growing trend of globalization in educational technology research. Partnership opportunities are also possible between centers in countries with advantages, for example, between researchers in the United States, Europe, and Asia, with the potential to produce more comprehensive cross-regional findings and expand the generalization of immersive learning practices, especially in AR, VR, and MR in science education, which are effective and influential at the global level (Mallek et al., 2024; Matovu et al., 2023; Radianti et al., 2020; Tene et al., 2024). Advancing the integration of immersive learning in education requires ongoing collaboration between policymakers, educators, researchers, and technology developers.

4. Conclusion

This bibliometric analysis of immersive learning research, encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), in science education over the period 2015 to 2025 demonstrates a definitive transition from an initiation phase to a stage of exponential scholarly growth, most pronounced during the period 2020–2025. The analysis identifies Johannes Huwer as the most productive author, *Education Sciences* as the leading publication venue, and University College Cork as the most prolific contributing institution. Research output within this domain is predominantly anchored in VR-based approaches, with AR serving as a principal complementary technology, collectively directed toward enhancing conceptual understanding, student engagement, and overall learning experiences in science education. The intellectual core of the field is characterized by VR and student-centered learning, progressively interconnected with thematic areas including STEM education, e-learning, game-based learning, and psychopedagogical dimensions. Thematic mapping further reveals that VR, students, and education constitute foundational motor themes; AR and educational technology represent stable and well-established themes; MR and virtual environments emerge as developing research frontiers; and game-based learning is identified as a promising trajectory for future scholarly exploration. Geographically, research output remains heavily concentrated in the United States, Germany, and China, attributable to the high density of immersive technology developers, differential research funding structures, strategic policy orientations, and distinct national education priorities in these countries. The relatively modest international collaboration rate of 22.34% further underscores the existence of considerable untapped potential for expanding cross-national research partnerships in this field.

References

Agrawal, S., Simon, A., Bech, Sø., BÆrentsen, K., & Forchhammer, Sø. (2020). Defining immersion: Literature review and implications for research on audiovisual experiences. *AES: Journal of the Audio Engineering Society*, *68*(6), 404–417. https://doi.org/10.17743/jaes.2020.0039

Ahmadi, S. B. B., & Gilardi, M. (2024). *Work-in-Progress—Immersive Learning: Challenges and Trends*. 34–40. https://doi.org/10.56198/u6c0wv2uh

AlAli, R., Wardat, Y., Aboud, Y. Z., & Alhayek, K. A. (2025). The effectiveness of using augmented reality technology in science education to enhance creative thinking skills among gifted eighth-grade students. *Eurasia Journal of Mathematics, Science and Technology Education*, *21*(6), em2644. https://doi.org/10.29333/ejmste/16416

Alhebaishi, S., Stone, R., & Ameen, M. (2025). Emotional engagement and teaching innovations for deep learning and retention in education: A literature review. *International Journal of Advanced Computer Science and Applications (IJACSA) 16.3 (2025).* https://doi.org/10.14569/Ijacsa.2025.0160304

Aljabari, A., Moreb, M., Sarsour, T., & Khemaja, M. (2025). Exploring Metaverse Technologies in E-Learning: Methods, Benefits, Challenges, and Future Agenda. *2025 International Conference on Smart Learning Courses (SCME)*, 7–14. https://doi.org/10.1109/SCME62582.2025.11104885

Anni Hanifan Muslima. (2025). Perancangan Media Pembelajaran Organel Sel Berbasis Virtual Reality. *Barik*, *7*(1), 113–127. https://doi.org/10.26740/jdkv.v7i1.65904

Avila-Garzon, C., Bacca-Acosta, J., Duarte, J., & Betancourt, J. (2021). Augmented Reality in Education: An Overview of Twenty-Five Years of Research. *Contemporary Educational Technology*, *13*(3). https://doi.org/10.3390/mti5070037

de Figueiredo, L. D. F., da Silva, N. C., & Prado, M. L. Do. (2022). Primary care nurses' learning styles in the light of David Kolb. *Revista Brasileira de Enfermagem*, *75*(6). https://doi.org/10.1590/0034-7167-2021-0986

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

Fidas, C., Belk, M., Portugal, D., & Pitsillides, A. (2021). Privacy-preserving biometric-driven data for student identity management: Challenges and approaches. *Adjunct Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization*, 368–370. https://doi.org/10.1145/3450614.3464470

Gusteti, M. U., Musdi, E., Dewata, I., & Md. Rasli, A. (2025). A Ten-Year Bibliometric Study on Augmented Reality in Mathematical Education. *European Journal of Educational Research*, *14*(3), 723–741. https://doi.org/10.12973/eu-jer.14.3.723

Harnal, S., Sharma, G., Anupriya, Mishra, A. M., Bagga, D., Saini, N., Goley, P. K., & Anupam, K. (2024). Bibliometric mapping of theme and trends of augmented reality in the field of education. *Journal of Computer Assisted Learning*, *40*(2), 824–847. https://doi.org/10.1111/jcal.12899

Hine, E., & Floridi, L. (2024). Artificial intelligence with American values and Chinese characteristics: a comparative analysis of American and Chinese governmental AI policies. *Ai & Society*, *39*(1), 257–278. https://doi.org/10.1007/s00146-022-01499-8

Hollister, B., Nair, P., Hill-Lindsay, S., & Chukoskie, L. (2022). Engagement in Online Learning: Student Attitudes and Behavior During COVID-19. *Frontiers in Education*, *7*. https://doi.org/10.3389/feduc.2022.851019

Hou, Y. (2024). Study on the Application of Virtual Reality Technology in Cross-Border Higher Education. *Computer Sciences & Mathematics Forum*, *8*(1), 97. https://doi.org/10.3390/cmsf2023008097

Kuhail, M. A., Elsayary, A., Farooq, S., & Alghamdi, A. (2022). *Exploring Immersive Learning Experiences : A Survey*. https://doi.org/10.3390/informatics9040075

Lampropoulos, G. (2025). Combining Artificial Intelligence with Augmented Reality and Virtual Reality in Education: Current Trends and Future Perspectives. *Multimodal Technologies and Interaction*, *9*(2). https://doi.org/10.3390/mti9020011

Lampropoulos, G., & Evangelidis, G. (2025). Learning Analytics and Educational Data Mining in Augmented Reality, Virtual Reality, and the Metaverse: A Systematic Literature Review, Content Analysis, and Bibliometric Analysis. In *Applied Sciences* (Vol. 15, Issue 2, p. 971). https://doi.org/10.3390/app15020971

Lin, H. K., & Lu, Li-wen, Lu, R.-S. (2024). *Integrating Digital Technologies and Alternate Reality Games for Sustainable Education : Enhancing Cultural Heritage Awareness and Learning Engagement*. https://doi.org/10.3390/su16219451

Mallek, F., Mazhar, T., Faisal Abbas Shah, S., Ghadi, Y. Y., & Hamam, H. (2024). A review on cultivating effective learning: synthesizing educational theories and virtual reality for enhanced educational experiences. *PeerJ. Computer Science*, *10*, e2000. https://doi.org/10.7717/peerj-cs.2000

Matovu, H., Ungu, D. A. K., Won, M., Tsai, C.-C., Treagust, D. F., Mocerino, M., & Tasker, R. (2023). Immersive virtual reality for science learning: Design, implementation, and evaluation. *Studies in Science Education*, *59*(2), 205–244. https://doi.org/10.1080/03057267.2022.2082680

Morris, T. H. (2020). Experiential learning–a systematic review and revision of Kolb's model. *Interactive Learning Environments*, *28*(8), 1064–1077. https://doi.org/10.1080/10494820.2019.1570279

Muzata, A. R., Singh, G., Stepanov, M. S., & Musonda, I. (2024). *Immersive Learning : A Systematic Literature Review on Transforming Engineering Education Through Virtual Reality*. 480–505. https://doi.org/10.3390/virtualworlds3040026

Mystakidis, S., & Lympouridis, V. (2023). Immersive Learning. *Encyclopedia*, *3*(2), 396–405. https://doi.org/10.3390/encyclopedia3020026

Nawaz, S. S., Riyath, M. I. M., Nayak, R., Najim, M. M. M., Alotaibi, B. A., Sanjeetha, M. B. F., & Murshidi, G. A. (2025). Trends and future direction of metaverse in education: a bibliometric analysis. *IEEE Access*. https://doi.org/10.1109/ACCESS.2025.3588007

Nedeva, V., Dineva, S., & Ducheva, Z. (2025). The Impact Of Metaverse Technologies On Project-Based Learning In Engineering Education. *Edulearn25 Proceedings*, 2816–2825. https://doi.org/10.21125/edulearn.2025.0783

Pezzino, S., Luca, T., Castorina, M., Puleo, S., & Castorina, S. (2025). Transforming Medical Education Through Intelligent Tools: A Bibliometric Exploration of Digital Anatomy Teaching. In *Education Sciences* (Vol. 15, Issue 3, p. 346). https://doi.org/10.3390/educsci15030346

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, *147*, 103778. https://doi.org/https://doi.org/10.1016/j.compedu.2019.103778

Samala, A. D., Rawas, S., Rahmadika, S., Criollo-C, S., Fikri, R., & Sandra, R. P. (2025). Virtual reality in education: global trends, challenges, and impacts—game changer or passing trend? *Discover Education*, *4*(1), 229. https://doi.org/10.1007/s44217-025-00650-z

Setiawan, B., & Winarno, A. (2024). Global Trend On Used Immersive Virtual Reality In Science Education: Bibliometric Analysis. *Dikoda Jurnal Pendidikan Sekolah Dasar*, *5*(2), 96–106. https://doi.org/10.37366/jpgsd.v5i2.5206

Setiawan, B., & Winarno, A. (2025). *Global Trend On Used Immersive Virtual Reality In Science Education : Bibliometric Analysis Global Trend On Used Immersive Virtual Reality In Science Education : Bibliometric Analysis*. *January*. https://doi.org/10.37366/jpgsd.v5i2.5206

Shonfeld, M., Zidan, W., Yazbak Abu Ahmad, M., Cohen Liverant, R., Lieber-Milo, S., & Amichai-Hamburger, Y. (2025). Virtual Bridges: Enhancing Intercultural Competence Among Pre-Service Teachers Through 3D and Video-Conferencing Platforms. *Education Sciences*, *15*(10), 1296. https://doi.org/10.3390/educsci15101296

Spangenberger, P., Matthes, N., Geiger, S., Draeger, I., Kybart, M., Schmidt, K., Kruse, L., & Felix, K. (2023). How to bring immersive VR into the classroom: German vocational teachers' perception of immersive VR technology. *Journal of Technical Education*, *11*(1), 91–106. https://doi.org/10.48513/joted.v11i1.257

Teguh Brahmana, Taufiq, & Rizki Suwanda. (2025). Pengembangan Aplikasi Augmented Reality Untuk Pembelajaran Biologi Menggunakan Marker Based Tracking Pada Platform Android.

Rabit : Jurnal Teknologi Dan Sistem Informasi Univrab, *10*(2), 1063–1073. https://doi.org/10.36341/rabit.v10i2.6460
Tene, T., Marcatoma Tixi, J. A., Palacios Robalino, M. de L., Mendoza Salazar, M. J., Vacacela Gomez, C., & Bellucci, S. (2024). Integrating immersive technologies with STEM education: a systematic review. *Frontiers in Education*, *Volume 9-2024*. doi: 10.3389/feduc.2024.1410163
Ullah, R., Asghar, I., & Griffiths, M. G. (2022). An integrated methodology for bibliometric analysis: a case study of internet of things in healthcare applications. *Sensors*, *23*(1), 67. https://doi.org/10.3390/s23010067
Urban, M. (2025). How Oral Traditions Develop: a Cautionary Tale on Cultural Evolution from the Quechuanspeaking Andes. *Humanities and Social Sciences Communication*, *12(1)*, 1–13. https://doi.org/10.1057/s41599-025-05335-4.
Veer, V., Phelps, C., & Moro, C. (2022). Incorporating Mixed Reality for Knowledge Retention in Physiology, Anatomy, Pathology, and Pharmacology Interdisciplinary Education: A Randomized Controlled Trial. *Medical Science Educator*, *32*(6), 1579–1586. https://doi.org/10.1007/s40670-022-01635-5
Zhao, X., Ren, Y., & Cheah, K. S. L. (2023). *Leading Virtual Reality (VR) and Augmented Reality (AR) in Education : Bibliometric and Content Analysis From the Web of Science (2018 – 2022). September*, 1–23. https://doi.org/10.1177/21582440231190821
Zhuang, T., Xu, X., & Zhang, Y. (2024). Contextualizing and visualizing abstract theoretical knowledge for situated learning: large-scale VR-supported higher education in China. *Virtual Reality*, *29*(1), 4. https://doi.org/10.1007/s10055-024-01075-z