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IMMERSIVE LEARNING IN HIGHER EDUCATION: A SYSTEMATIC REVIEW OF VIRTUAL REALITY APPLICATIONS, LEARNING OUTCOMES, AND IMPLEMENTATION CHALLENGES

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ABSTRACT
Virtual Reality (VR) has become one of the most revolutionary technologies in the education sector to help create immersive and interactive learning experiences, thereby increasing student engagement and retention of knowledge. This paper will discuss the effectiveness, accessibility issues and implementation problems of VR in learning. In this study, a systematic literature review of existing literature conducts the systematic literature review with the help of Preferred Reporting Items of Systematic Review and Meta-Analysis (PRISMA). The Scopus database was selected in order to gather high quality data and coverage. We selected seventy-two studies that met the eligibility criteria and they were related to a broad spectrum of topics and possessed various goals. The results show that VR has been applied across a range of different learning modalities, thus improving the formal and informal education setting and it facilitates affective engagement, skill acquisition, and learner motivation. VR provides engagements that encourage active engagement and practice of complicated actions. Although it has potential, VR implementation is usually affected by increased implementation costs, technological limitations, cybersickness, cognitive load and insufficient pedagogical readiness among the teaching community that suggests that most of the studies rely on short term measurement and self-reported measures, which necessitate longitudinal evidence and standardized assessment systems. In this study, VR is highlighted as gaining high educational effect when it becomes part of blended learning models and user-centered design principles. Future research should emphasize accessibility-oriented development, collaborative virtual environments and rigorous evaluation of real-world learning transfer to enhance universally accessible immersive education.

KEYWORDS Virtual Reality, Higher education, Immersive learning, Educational technology, Systematic review

1 INTRODUCTION

Virtual Reality is a technology that involves simulation and provides an environment where a person can engage with a 3D world in real-time using a set of head-mounted displays, known as Immersive Virtual Reality (iVR) (Predescu et al., 2023). This contrasts with non-immersive VR which typically involves 2D screens (Luke et al., 2024). It allows users to engage themselves in a computer-generated world, which virtually isolates them in relation to the real world (Azzam et al., 2024). This immersive nature creates a feeling of presence to allow users to reproduce real-life occurrences, even in the restricted environment of their homes (Owusu & Luke, 2024). VR is seen as a powerful tool which can transform education by providing participatory and interactive experiences, especially in abstract-based courses, such as physics, mathematics, and engineering (Predescu et al., 2023). It is a pedagogical instrument which assists students focus on, become engaged and productive regarding feedback (Ema Wulansari et al., n.d.)

The history of Virtual Reality dates back to the Sensorama of Morton Heilig in the 1950s, a precursor to other multimodal virtual environments that later became the foundation of the modern VR systems used in experiences (Crogman et al., 2025). The earliest work of Ivan Sutherland, including the Ultimate Display of 1968 and the Sword of Damocles style of head-mounted display, created in cooperation with Bob Sproull, showed the potential of immersive technologies to integrate physical and digital worlds and provide new possibilities to realistic simulations and learning through experience. (Crogman et al., 2025). Though the idea has always been based on the concept of entertainment, VR has evolved to be used in an educative purpose, with audio, visual or even haptic feedback, to produce real and interactive simulation. Jaron Lanier not only coined the term Virtual Reality in the 1980s, but he had also founded VPL Research, which led to the future of VR as a part of an immersive and experiential learning setting (Crogman et al., 2025). The pedagogical potential of VR was not fully achieved until the 2010s, with the launch of the Oculus Rift, despite the innovatively-considered potential in the 1990s by such companies as Sega and Nintendo. Large corporations, such as Google, Sony, and HTC began to take an interest in the Oculus Rift and began creating Virtual Reality platforms to use in immersive learning. Those platforms allow students and users to take virtual field trips and simulated lab experiences, which enables them to study more complex scientific theories and historic locations in ways previously unattainable (Crogman et al., 2025). Immersive VR has changed the way schools work by giving students a lot of depth with high-quality graphics and interesting content through head-mounted displays(Ema Wulansari et al., n.d.). It has evolved from an idea of the future into a groundbreaking resource for enhancing learning experiences (Criollo-C et al., 2024). As advancements in science and technology occur, the use of virtual simulation in education has grown significantly (Gao et al., 2023). The spread of immersive technologies, especially the resurgence of VR in the marketplace, is creating a fresh opportunity for education (Kasapakis et al., 2023)

Virtual Reality (VR) technology is revolutionizing education by offering distinct opportunities for engaging and hands-on learning experiences (Zaatar et al., 2024). The employment of VR in engineering education has demonstrated a 60% enhancement in learning through hands-on experiments compared to conventional instructional methods (Anjos et al., 2024). Furthermore, 83% of participants indicated a higher level of satisfaction with the implementation of VR (Anjos et al., 2024). The ability of immersive virtual reality to promote generalisation across diverse scenarios and characters further increases its educational significance. For instance, students can, practice CPR in a moving ambulance or on a city sidewalk, or they may engage in a simulation as the foreman of a construction team or as the roofer (Luke et al., 2024). By utilising iVR, educational institutions can lower overall training expenses compared to traditional approaches, making skill development more effective and widely available (Luke et al., 2024).(Di Natale, Repetto, et al., 2024) Di Natale, Repetto, et al., Highlights the necessity for research on iVR applications to evaluate their effectiveness and relevance because of the extensive range of opportunities presented by immersive technologies (such as virtual lectures, simulations, and virtual tours). It is essential to further investigate educational methods that originate from VR, as well as the terminology that facilitates learning in VR and practices that are appropriate for this medium. Although we have examined how existing learning theories align with VR-supported settings, researchers must persist in exploring how to maximise the benefits of VR environments and the unique experiences they offer (Rodolico & Hirsu, 2023). Nevertheless, there is a need for more research on the application of VR in educational methodologies.

This study aims to identify major research trajectories, thematic advancements, and persistent barriers by addressing these gaps. To achieve this, the following research questions are suggested to lead an extensive investigation of the global VR research landscape and its educational implications:

RQ1 What are the recent key publication trends and primary research themes in VR-related educational research?

RQ2 What learning outcomes and pedagogical benefits have been reported?

RQ3 What are the key challenges associated with implementing Virtual Reality in education, and what solutions have been proposed in the literature to mitigate these challenges?

RQ4 What are the gaps and future research directions that emerge from the literature?

1.1 Research Contribution

The review fits into the dynamic discussion of immersive technologies in education as it presents a comprehensive synthesis of the recent studies on the Virtual Reality-supported learning environments. Whereas the past reviews have analyzed VR applications in cases of isolated disciplinary aspect, the current study incorporates research findings on various domains of education to identify general pedagogical trends and new research opportunities. Through a systematic review of the literature published between 2023 and 2025, the present review identifies the current trends in immersive learning after the recent years of the accelerated digitalization of the educational process. Besides mapping key research themes, the research assesses learning outcomes in terms of affective, cognitive, and psychomotor aspects and determines the main obstacles to the use of VR in the educational arena. With the help of this integrative approach, the review provides an organized insight into the current research trends and represents the future research priorities to the successful and inclusive application of immersive technologies in higher education.

2 METHODOLOGY

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines(Page et al., 2021) (See Fig. 1) were followed to conduct a systematic literature review on the application of Virtual Reality (VR) in education.

2.1 Literature Search Process

The academic database Scopus was used to do a full literature search**.** Scopus was chosen as the primary database due to its wide multidisciplinary coverage and comprehensive indexing of peer-reviewed journals across education, technology, and human–computer interaction. This facilitated the effective search of recent VR-based educational research in a single search system. Although other databases might also comprise the needed literature, Scopus offered the benefit of consistent metadata and simplified screening. The authors admit that the utilization of a single database can have omitted some domain-specific publications. The search strategy used several combinations of keywords based on Virtual Reality and education, which focused on the learning outcomes and educational applications. The search was narrowed down with the use of operators (AND, OR). This search query was used in one or more of the following fields: title, abstract, or keywords (see Table 1). At least one keyword was used to identify relevant articles by combing them, to get the studies that specifically covered the use of VR in education cases.

2.2 Inclusion and Exclusion Criteria

In the case of the first screening, the articles that were retrieved were filtered using predefined inclusion and exclusion criteria (see Table 2). The only peer-reviewed journal articles made in English and published within the given time frame (20232025) were included. The review included the studies published in 2023-25 to reflect the recent post-pandemic changes in immersive learning as it represents a rapid technological progress and a growing institutional implementation of VR in educational activities. This period brings out the existing practices and new issues, but the previous fundamental researches were omitted. Excluded papers were conference papers, book chapters, editorials, and non-empirical studies.In the next title and abstract screening, the studies were selected

Criteria	**Inclusion**	**Exclusion**
Time span	2023-2025	<2023
Literature type	Article	Conference papers, Book chapters, review, Editorial
Language	English	Non-English
Source type	Journal	Trade journal
Publication stage	Final	Press
Keywords	virtual reality, VR, immersive technology, immersive learning, XR, student learner, education, learning, teaching, training, higher education, experiential learning	All other keywords
Open access	All open access	Restricted Access
Screening		
Title and abstract	Existence of predefined keywords in the titles and abstracts were included in the study.	
Full text	The relevant papers that have been included in this study are those that discuss the predefined keywords.	

according to the following criteria:

a) The study investigated VR as an instructional or learning tool in education.
b) The study concentrated on educational settings (school, majorly higher education, or professional training)
c) The study reported learning-related outcomes associated with engagement, achievement, skills, or perception
d) The sample population comprised of students or learners

Only studies that met all the above conditions were included for comprehensive examination and final analysis.

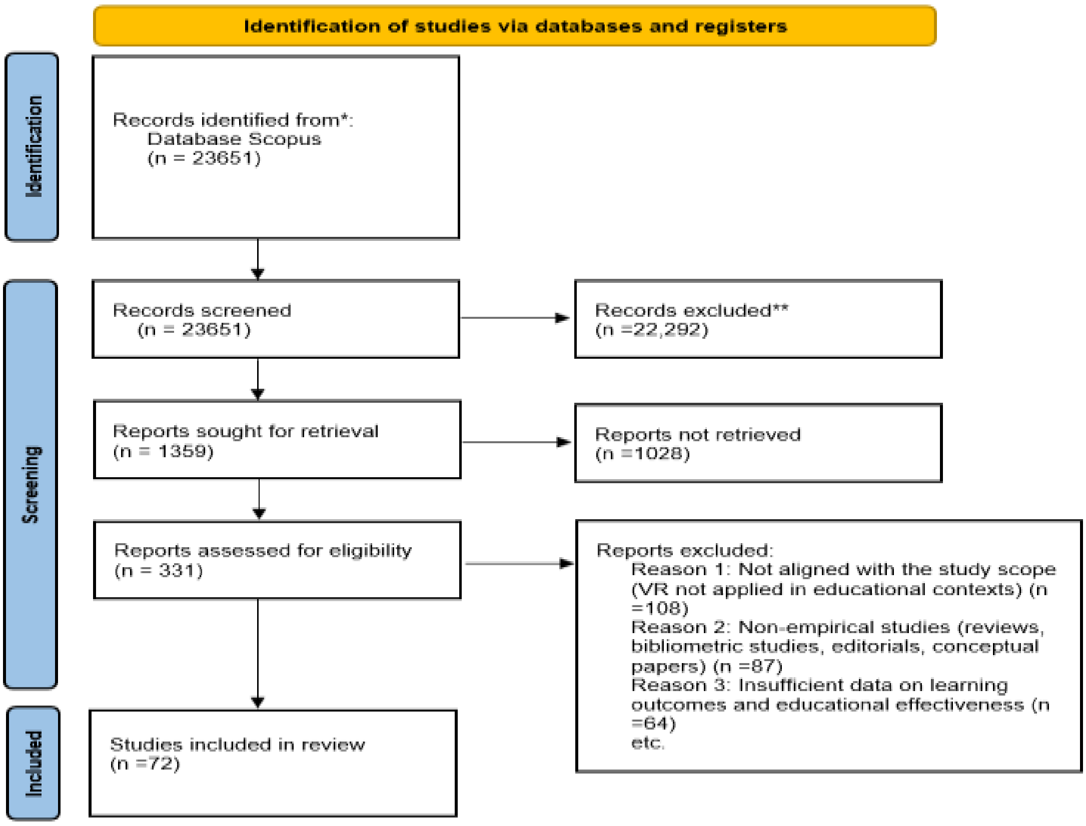
Table 1: Search terms. Virtual Reality-related search terms and education-related search terms were joined by the AND operator. “*” denotes the wildcard character

Database	Search terms
Scopus	("Virtual reality" OR VR OR "immersive technology" OR "immersive learning" OR XR) AND ("education" OR "learning" OR "teaching" OR "training" OR "higher education" OR "experiential learning") AND ("student" OR "learner")

Table 2: Inclusion and exclusion criteria used to systematically filter studies based on publication period, source type, language, accessibility, and relevance to VR in education.

PRISMA framework

Fig. 1 PRISMA flow diagram



Conceptual Framework

Fig. 2 Conceptual framework of VR-based learning Source: Authors creation

The theoretical framework used in this research demonstrates the correlation between immersive virtual reality technologies and learning outcomes. VR technologies establish immersive learning systems that are interactive, present, and simulated. These characteristics affect the cognitive, emotional and behavioural processes of learners in the learning activities. These processes make learning in cognitive, affective, and psychomotor dimensions, as students experience virtual environments. Contextual factors such as the design of the instruction, the preparedness of instructors to conduct learning, the institutional support, and the availability of technological infrastructure are also known to affect the effectiveness of VR-based learning. This framework gives a systematic outlook of the role of immersive technologies in enhancing learning in the higher education setting.

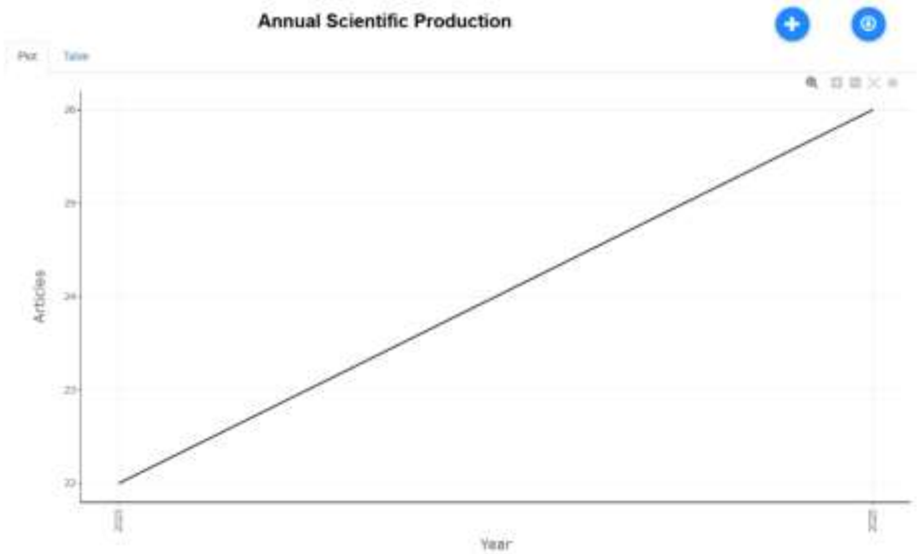
3 RESULTS AND DISCUSSION

This part includes critical analysis of the existing research studies conducted in order to answer the above research questions and comment on our findings, discuss the limitations inherent in our research and provide recommendations on how further studies can be conducted.

3.1 Key Publication Trends in VR-Related Educational Research (RQ1)

The review of VR-related educational sources published between 2023 and 2025 is a sign of a steady increase in the amount of scholarly activity, as the number of publications dedicated to immersive learning technologies has increased over time. The annual scientific output also enhanced by 22 publications in 2023 to 26 publications in 2025 (see Fig. 3), indicating that there was a continuous momentum of research over the three years. This incremental trend can be attributed to the fact that the growth rate of VR is 8.71 per year, which implies that VR is becoming a recognised pedagogical strategy and not an experimental educational resource. The number of publications was 72 research articles published in 50 different sources, which indicates the wide spread of the journals, as well as the multidisciplinary character of VR research in education. The authors were 290 in total and the average authors in a document were 4.11 indicating high cooperation. The number of single-authored studies was only eight, which shows that the majority of research was done in the work of a team and with the influence of interdisciplinary work. Moreover, 23.61% of the publications were international co-authored, which proves the moderate level of collaboration and mutual scientific interest in VR-based education in the world. The sources are also relatively new, with the mean age of documents being 1.94 years old, indicating that this review represents the current trends in the research of the immersive learning. Even with the limited publication period, articles obtained a mean of 7.83 citations per document, which indicates that studies devoted to VR influence the academic environment in the first place and guarantee the growth of interest to VR-oriented educational research. New publications place emphasis on applied educational settings, namely, experiential learning, post-secondary education and learner interaction.(Tay et al., 2025) Conducted research on VR-based experiential learning environments and showed a positive effect, but (Johansen et al., 2025) examined immersive simulations in educational training. Similarly, (Sandoval et al., 2025) Developed a university-level VR platform that exhibited enhancement in student performance, and (N. Chen et al., 2025) Explored immersive VR applications in sustainable education, indicating a shift towards outcome-oriented implementations. The trends of publications observed suggest that VR in education is no longer in its initial stages of adoption, but a more research-based area. The steady increase in productivity, as well as the broadening of cooperation and the emphasis on applied research, emphasizes the fact that VR is becoming an increasingly important part of changing the modern teaching and learning practices.

Fig. 3 Annual scientific production of articles



Source: R Studio

3.2 Primary Research Themes in VR-Related Educational Research (2023–2025)

The main themes of research in VR-based educational research published between 2023 and 2025 were determined by analyzing the co-occurrences of keywords (see Fig.4), thematic mapping (see Fig.5) and qualitative synthesis of abstracts. The outcomes have demonstrated that there are six prevailing thematic areas that are associated with both the existing and upcoming trends in the study of immersive learning.

3.2.1 VR–Enabled Learning and Student Engagement

The most evident is the use of the VR to improve the student learning experiences and engagement.(Kristiansen & Lauridsen, 2025) It is demonstrated that the use of VR in learning environments can increase the levels of student engagement through immersive experiences and providing interactive learning and enhancing learner engagement. The percentage of studies that are devoted to interaction with learners, to immersion, and to the use of e-learning is substantial. Studies have consistently shown that VR allows participation and active engagement, placing students in the center of the immersive instructional design.(Sandoval et al., 2025) created a VR learning platform at a university and expressed a better learner engagement, whereas (Tay et al., 2025) emphasized the efficiency of VR learning in the hands-on learning context. Likewise, (Johansen et al., 2025) Investigated immersive simulations and highlighted their interactive and exploratory learning. It is Reported that immersive VR improves student engagement through active engagement of learners and improved interaction in e-learning programs(Z. Chen & Chen, 2025).

3.2.2 Human-Centered Educational Applications of VR

Recent literature underlines that human-centred VR environments in education focus on the experience of the learner by incorporating principles of intuitive interface design, usability, and psychological engagement, proving that an immersive environment can have an enormous impact on the comfort, motivation, and meaningful interaction when a human is in the centre of technological design (Q. Chen, 2025; Giussani et al., 2025; Hammouda et al., 2025). One of the most common themes is the experience of the learners, their usability, and psychological involvement. The research in this cluster focuses on the effect of VR on cognition, perception, and emotional response by viewing VR as a medium that modulates human learning processes instead of just conveying information. (Ferguson et al., 2025) Revealed user experiences in VR learning settings, noting the significance of interface design and comfort. (Tay et al., 2025) showed that learners were satisfied with immersive settings and that usability is an important factor that would lead to a successful introduction of VR.

3.2.3 Immersive VR in Higher Education

Recent findings show that immersive VR is being progressively introduced to higher education to facilitate virtual learning environments and simulation-based learning and allow students to learn complex tasks in real environments and show positive outcomes on engagement and academic achievement (Artiles-Rodríguez et al., 2025; Gerard et al., 2025). Immersive VR in higher education is a key theme of transition. Many studies explore virtual classrooms, simulations, and experiential learning frameworks in university settings. (N. Chen et al., 2025) Demonstrated the use of immersive VR in sustainable education, indicating enhanced conceptual understanding, whereas (Sandoval et al., 2025) Revealed that VR platforms facilitate improved academic performance among university students These findings indicate an increasing transition towards outcome-focused VR integration in higher education.

3.2.4 Experiential and Problem-Based Learning Approaches

A more specialised but conceptually mature theme involves experiential and problem-based learning. Recent empirical evidence indicates that VR-supported experiential and problem-based learning environments facilitate active learner participation in authentic scenarios, thereby enhancing practical skill acquisition, strengthening problem-solving competencies, and supporting the effective transfer of theoretical knowledge to real-world applications (P. H. Chen et al., 2024; Crogman et al., 2025). Research in this area utilised VR to simulate real-world scenarios, enabling learners to practice skills in controlled virtual environments. (Tay et al., 2025) Demonstrated that experiential VR enhances development of practical competencies, emphasizing VR's significance in facilitating authentic learning experiences that bridge theory and practice.

3.2.5 Integration of Educational Technology and Virtual Environments

An emerging theme emphasizes the integration of VR with broader educational technologies, encompassing virtual environments and hybrid immersive systems. current research suggests that combining virtual environments with blended learning approaches supports the development of integrated digital ecosystems, fostering adaptable teaching practices, stronger student engagement, and better coordination between educational technologies and learning objectives (Brylska et al., 2024; Hu-Au, 2024; Luke et al., 2024). Studies examine how VR enhances existing digital learning ecosystems and facilitates adaptable instructional design. (Johansen et al., 2025) Examined the potential of VR to augment technology-mediated education, reflecting growing interest in blended and multimodal learning frameworks.

3.2.6 Learner Motivation, Presence, and Emotional Engagement

One of the emerging themes covers the affective aspects of VR learning such as motivation, presence sense, and emotional experience. Recent studies suggest that immersive VR environments can significantly enhance motivation and emotional experiences of students, as such environments can produce strong experience of presence, which in turn positively affects not only student engagement but educational experiences in general (Artiles-Rodríguez et al., 2025; Fröhlich et al., 2025; Mulders et al., 2025). (Kurbanbekov et al., 2025) Reported more learner motivation under VR-assisted physics education, whereas(N. Chen et al., 2025) Described cognitive and emotional engagement in immersive rural education. Though not yet as much represented, the theme is an indication of growing interest in the psychological processes of VR-based learning.

Table 3 presents a synthesis of the primary research themes identified through keyword co-occurrence analysis as in Fig. 3 and thematic mapping, as in Fig. 4. The classification into motor, basic, niche, and emerging themes is based on centrality and density measures, reflecting the conceptual development and relevance of each theme within the VR-education research landscape.

Table 3: Primary research themes

Theme No.	Primary Research Theme	Key Focus Areas	Relevant Authors
1	VR-Enabled Learning and Student Engagement	Immersive learning, e-learning, learner interaction, engagement	(Z. Chen & Chen, 2025; Kristiansen & Lauridsen, 2025; Sandoval et al., 2025)
2	Human-Centred Educational Applications	Learner experience, usability, psychological engagement	(N. Chen et al., 2025; Giussani et al., 2025; Hammouda et al., 2025)
3	Immersive VR in Higher Education	Virtual classrooms, simulations, academic performance	(Artiles-Rodríguez et al., 2025; Gerard et al., 2025; Sandoval et al., 2025)
4	Experiential and Problem-Based Learning	Hands-on learning, real-world simulation, skill development	(P. H. Chen et al., 2024; Crogman et al., 2025; Tay et al., 2025)
5	Educational Technology Integration	Virtual environments, blended learning, digital ecosystems	(Brylska et al., 2024; Hu-Au, 2024; Luke et al., 2024)
6	Motivation, Presence, and Emotional Engagement	Learner motivation, presence, affective outcomes	(Artiles-Rodríguez et al., 2025; Fröhlich et al., 2025; Mulders et al., 2025)

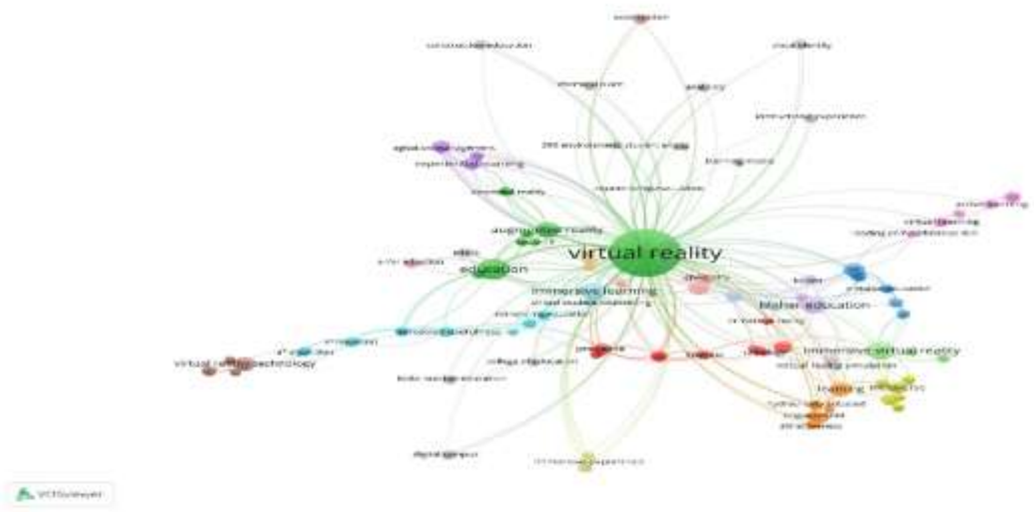


Fig. 4 Co-occurrence network of author keywords **Source: VOSviewer**

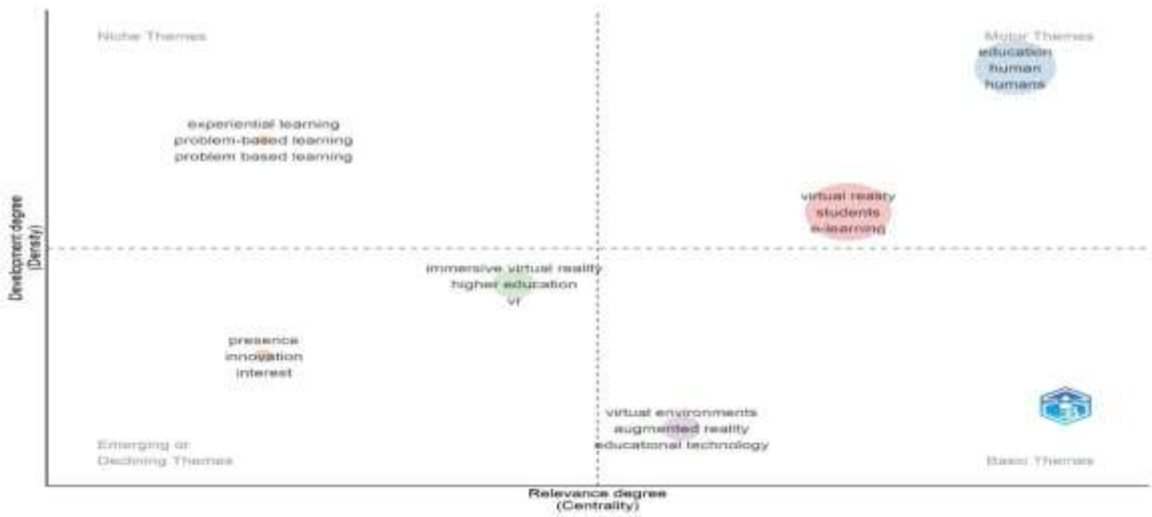


Fig. 5 Thematic map of research trends in VR in Education **Source: R Studio**

3.3 Learning Outcomes and Pedagogical Benefits Reported in VR-Based Educational Research (2023–2025) (RQ2)

Across the reviewed studies, VR is identified as a versatile educational tool that enhances learning across affective, cognitive, and psychomotor domains, while simultaneously transforming pedagogical practices.

3.3.1 Affective Learning and Emotional Engagement

The effect of VR-based instruction on affective learning has been reported as one of the most reliable results of the instruction. Some studies report a positive correlation of high strength between the sense of presence of learners in a VR environment and their performance outcomes including empathy, perspective-taking, emotional engagement(Mulders et al., 2025). The use of immersive experiences makes students emotionally engaged with learning material, which will allow them to learn about the experiences of other people, particularly in healthcare, psychology, and social sciences (Z. Chen & Chen, 2025; Helle et al., 2023; Tay et al., 2025). VR simulation has shown significant decrease in anxiety and increase in confidence, especially in context of performance, like public speaking and clinical training (Sandoval et al., 2025; Wu et al., 2025). Learners have stated that they have better emotional control and less stressful situations when they practice in virtual space where they are not afraid of being judged by others, which leads to the establishment of emotionally safe learning environments (Sandoval et al., 2025). Such affective benefits often led to a greater desire to be motivated, curious, and enjoy the course content, which solidifies the inclination of the learners to the active use of course content (Dewi et al., 2024; Fröhlich et al., 2025; Lin et al., 2023).

3.3.2 Cognitive Outcomes and Knowledge Acquisition

Evidence concerning cognitive learning outcomes reveals a more complex scenario. (Mulders et al., 2025) Mulders et al., reported no direct correlation between VR presence and factual knowledge acquisition, numerous studies indicated significant improvements in comprehension, academic achievement, and conceptual understanding when VR was compared with traditional instructional approaches (Crogman et al., 2025; Dewi et al., 2024; Di Natale, Bartolotta, et al., 2024). Immersive visualization facilitates learners to interact with abstract or complex concepts such as anatomical structures, programming algorithms, or engineering systems making difficult content more accessible(Ferguson et al., 2025; Z. Liu & Wang, 2024; Zaatar et al., 2024). Multiple other sources reported an increase in concentration, attention, and the efficiency of learning in the students who used head-mounted displays or interactive VR spaces(Lin et al., 2023; Z. Liu & Wang, 2024) Notably, knowledge transfer is also improved by VR. Immersive environments combined with the elements of a narrative help learners to connect the theoretical knowledge to the practical one better, which leads to improved knowledge retention and application in real life (Fröhlich et al., 2025; Luke et al., 2024; Mulders et al., 2025). However, numerous researchers report that VR can also present a higher cognitive load, particularly to a first-time student, which can hinder learning in tasks that require extensive reading or other complex processes(Çoban et al., 2024; Mulders et al., 2025). These results demonstrate the importance of a critical design of instructions.

3.3.3 Psychomotor Skills and Practical Competency Development

A major strength of VR is that it can facilitate the learning through skills. Students of different directions, such as medicine, engineering, machining, robotics, and physiotherapy, who have studied with the help of VR environments reported reduced rates of errors, reduced time to perform a task, and increased confidence in performing complex tasks such as surgery, crime-scene investigation, and working in a machine room (Ema Wulansari et al., n.d.; Ghrouz et al., 2025). Learning outcomes in VR environments included reduced error rates, reduced time to complete a task, and a greater sense of confidence in their capabilities to execute a complex task such as surgery, crime-scene investigation and handling machines (Crogman et al., 2025; Gerard et al., 2025). Such environments offer graceful failure, whereby learners can commit errors without any real-life repercussions and enable learners to perfect their abilities via repetition (Gerard et al., 2025; Luke et al., 2024).

3.3.4 Core Pedagogical Benefits of VR Integration

In addition to learning outcomes, the literature presents the multiple pedagogical advantages that VR as a transformative educational medium provides safe, secure, and risk-free learning experiences in experiential learning, particularly high-stakes learning (Gerard et al., 2025; Tay et al., 2025). Students are able to participate in some realistic simulations that otherwise would be too costly, unsafe, or impractical to recreate in more traditional classrooms. therefore, VR is a close supporter of active, constructivist learning. Students transition to the active consumption of content to exploration, hypothesis testing, and reflection, which support more profound conceptual change and meaning-making (Almisad et al., 2024; Di Natale, Bartolotta, et al., 2024). This learning by doing model will bridge the theory-practice gap and allow contextual and experience-based learning (Sandoval et al., 2025). Furthermore, immersive environments augment engagement and presence, encouraging students to become embodied participants rather than observers. Multisensory interaction enhances stronger working memory and sustained attention while accommodating diverse learning styles, particularly visual and kinesthetic learners (Dewi et al., 2024; Zaatar et al., 2024). similarly, VR promotes collaborative and inclusive learning. The virtual spaces are used to encourage peer interaction, remote learning and fair access to authentic learning opportunities, contributing to geographical and socioeconomic level barriers (Antonelli et al., 2023; Crogman et al., 2025). Finally, VR is more effective in instructions. Teachers have the opportunity to introduce the theoretical material and then practice its physical implementation, reducing the cost and time of training and making the learning process similar to the groups. (Dewi et al., 2024; Ema Wulansari et al., n.d.).

3.4 Key Challenges in Implementing VR in Education and Proposed Mitigation Strategies (RQ3)

The examined literature reveals that the implementation of VR in educational settings is limited by a multifaceted interaction of technical, physical, pedagogical, institutional, and socio-economic factors. Rather than isolated barriers, these challenges operate systemically, requiring coordinated responses across technological design, educational practice, and organizational policy.

3.4.1 Financial, Logistical, and Infrastructure Constraints

High implementation costs remain a significant obstacle to the adoption of VR. Organisations have huge financial burdens in terms of hardware purchase, software licensing, content development, maintenance and technical support (Brylska et al., 2024; Z. Chen & Chen, 2025; Marques et al., 2024; Tan et al., 2024). Such restrictions are high in particular in resource constrained environments. In addition to the needed initial investment, logistical challenges, such as the lack of headsets, the challenges of storage and charging devices, the need to schedule the work with large groups, and the dependence on the constant availability of a reliable internet connection all make the implementation scale more difficult (Crogman et al., 2025; Di Natale, Bartolotta, et al., 2024; Ema Wulansari et al., n.d.). The adoption of VR in education has been frequently constrained by the requirement of special technical skills, high financial costs, robust internet connectivity, and access to suitable equipment which, in turn, presents a strong obstacle to the widespread adoption (Grosser et al., 2023). To address these issues, researchers suggested shared-resource models, centralized VR laboratory, and organized equipment time-slot systems to maximize its utilization (Z. Chen & Chen, 2025; Crogman et al., 2025; Marques et al., 2024). Further recommendations include adoption of open-source or lightweight modular platforms compatible with lower-specification devices (Hammouda et al., 2025) and the development of institutional policies that prioritize long-term sustenance as compared to short-term experimentation (Tan et al., 2024)

3.4.2 Technical Instability and System Limitations

Technical unreliability remains a major problem. The lack of automatic saving features is also a common cause of program crashes, latency, software crashes, lag, controller disconnection, device incompatibility and loss of progress in students (Ferguson et al., 2025; Gerard et al., 2025). System level constraints such as sensor noise, tracking drift, and inaccurate scene reconstruction diminish realism and interactive fidelity (Crogman et al., 2025; Y. Liu, 2025), Limitations on system level performance include sensor noise, tracking drift and inaccurate reconstruction of the scene reduce realism and interactive fidelity [6,38], which often disrupts the learning process and distracts the educational purpose. Solutions presented include the use of automatic saving checkpoints, better error recovery and better user interface design (Gerard et al., 2025). Algorithms Technical optimization algorithms include advanced Simultaneous Localization and Mapping (SLAM) algorithms and support of the inertial measurement data to improve spatial accuracy.(Y. Liu, 2025). Moreover, offline or single-user modes are advisable in environments with unstable connectivity, in conjunction with organized orientation sessions and more explicit task instructions to mitigate initial misunderstanding (Ferguson et al., 2025; Hammouda et al., 2025).

3.4.3 Physical Discomfort and Health Implications

A significant percentage of learners experience cybersickness, which is marked by nausea, dizziness, headaches, eye strain, and exhaustion, occasionally manifesting within minutes of exposure (Azzam et al., 2024; Çoban et al., 2024; Zaatar et al., 2024). Hardware-related discomfort, including heavy headsets and improperly adjusted straps, further undermines user experience (Luke et al., 2024). Moreover, highly realistic avatars may induce the "uncanny valley" effect, resulting in emotional discomfort or distraction (Sandoval et al., 2025). To make things better we can move towards Mixed Reality environments to make hybrid experiences more stable (Azzam et al., 2024) , improve hardware performance by increasing frame rates and adding better tracking systems(Crogman et al., 2025), and use semi-realistic visual design to find a balance between ecological validity and user comfort (Sandoval et al., 2025). It has also been proven that letting students change their movement speed, field of view, and interaction modes can help lessen negative effects (Luke et al., 2024). Environmental factors, such as quiet and temperature-regulated VR environments enhance physical comfort (Çoban et al., 2024) (Çoban et al., 2024).

3.4.4 Cognitive Load and Learning Effectiveness

Although immersion is a defining feature of VR, several studies warn that excessive sensory stimulation can lead to cognitive overload, distracting from fundamental learning goals (Brylska et al., 2024; Crogman et al., 2025). Learners who are unfamiliar with VR often focus on learning how to operate the controllers rather than engaging with academic content. Also, immersive settings that require text-based tasks have been reported to increase cognitive load and, in certain instances, decrease the level of understanding in some situations(Çoban et al., 2024).(Adri et al., n.d.) Reported that though VR was found to be better at teaching students theoretical knowledge, its inability to recreate real-life sensory stimuli diminished its effect as an instructional tool. To reduce these impacts, researchers proposed preliminary warm-up sessions before formal training(Brylska et al., 2024), the instructional framework that focuses on interactive multimedia rather than on the text (Çoban et al., 2024), and gradual exposure to the high-anxiety tasks such as a speech in front of the audience (Sandoval et al., 2025). The combination of VR simulations and real-life experience of learning is widely justified as a form of conceptual understanding without compromising practical skills learning (Z. Chen & Chen, 2025; Hammouda et al., 2025).

3.4.5 Faculty Preparedness and Pedagogical Integration

One of the disruptive challenges has been low teacher readiness. According to many teachers, a shortage of technical skills, low confidence, and problems integrating VR experiences with the objectives of the curriculum are present (Di Natale, Repetto, et al., 2024; Rodolico & Hirsu, 2023). The resistance to the idea of leaving traditional educational models also restricts the widespread adoption (Brylska et al., 2024). Poor correspondence between VR content and teaching goals may lead to a lack of educational value (Rodolico & Hirsu, 2023). In the literature, there is a stress on the significance of specific professional growth and constant coaching to improve instructional competency (Z. Chen & Chen, 2025; Zaatar et al., 2024). VR training is recommended to use in the initial stages of educating teachers in order to increase the lasting pedagogical confidence (Rodolico & Hirsu, 2023). Educator-developer collaboration in the creation of content is regarded as a key to keeping pedagogical relevance(Di Natale, Repetto, et al., 2024). Importantly, VR is mostly described as a supporting, not a replacement to the conventional teaching methods (Hammouda et al., 2025).

3.4.6 Social Interaction, Inclusivity, and Assessment Challenges

The barriers to accessibility based on digital literacy, disabilities, and various degrees of familiarity with gaming environments also influence the engagement of the learners (Gerard et al., 2025). Another issue is assessment, where creative VR projects are challenging to measure, and other studies rely on small samples, which restricts generalizability (Marques et al., 2024; Zaatar et al., 2024) . According to the findings of (Viitaharju et al., 2023), Students have clearly stated that the virtual laboratory cannot serve as a substitute for the experience of being in a real, physical laboratory. Solutions such as synchronous multi-user VR environments to promote collaboration and teamwork (Ferguson et al., 2025), alternative learning paths (playthrough videos) to address the challenges in technologies faced by technically challenged students (Gerard et al., 2025), and structured assessment rubrics (that emphasize process-related criteria such as novelty, complexity, and usability) have been recommended (Marques et al., 2024) . In order to enhance the quality of the project and the results of learning, (Marques et al., 2024) suggested applying iterative checkpoints and frequent formative feedback.

3.5 Research Gaps and Future Directions in VR–Based Education (RQ4)

Despite the high potential of VR in enhancing learning experiences, the reviewed literature reveals that it suffers a myriad of persisting shortcomings that impede its transformation to a more traditional learning activity rather than being an experimental novelty. Such gaps include methodological rigor, integration of pedagogy, technological development, and issues on accessibility and inclusivity, which all forms an explicit agenda to be addressed in further research.

3.5.1 Methodological Rigor and Longitudinal Evidence

The most common issue in the existing studies is the lack of longitudinal and statistically significant findings. Long-term knowledge retention is not well studied, with most of the studies relying on short-term learning results that were assessed right after VR interventions. The researchers consistently support the idea of later measurements three to six months post-intervention to determine whether immersive learning leads to long-term cognitive gains (Anjos et al., 2024; Crogman et al., 2025; Sandoval et al., 2025). As a result, a large portion of empirical research has been conducted on small, descriptive samples up to 50 respondents, restricting their generalizability and statistical power (Rossoni et al., 2024; Sandoval et al., 2025). The future studies should thus focus on larger multi-institutional samples with a variety of disciplines and learner demographics to increase the external validity (Anjos et al., 2024; Ferguson et al., 2025). The other methodological gap is related to evaluation practices. The assessments that are currently being used mostly depend on self-reported perceptions such as satisfaction and anxiety. Further research needs to incorporate objective behavioural features to support the evidence-based adoption, such as the duration of eye-contact, posture consistency, vocal prosody, and task performance indicators (Sandoval et al., 2025). Furthermore, a failure to have standardized and defined formats of designing and assessing VR learning activities also complicates the process of cross-study comparisons, indicating the need to adopt common methodology standards (Anjos et al., 2024). Notably, there is a paucity of research done to determine the effectiveness of learning competencies in VR in real-life settings. Following up learners outside of virtual settings to real-world work or educational conditions is a key direction of the future to prove the practical effectiveness of immersive teaching (Ferguson et al., 2025; Sandoval et al., 2025).

3.5.2 Pedagogical Integration and Theoretical Development

Besides the methodological concerns, the literature shows that there is a major disconnect between technological innovation and educational goals. Many authors believe that VR applications are frequently implemented without any clear educational goals or due to innovation or institutional prestige (Johansen et al., 2025). Future studies ought to focus on curriculum-based frameworks that focus on discipline specific goals. There is an important gap in the undeveloped teaching models which are unique to immersive environments. Many contemporary efforts seek to modify conventional instructional models for VR, instead of creating "VR-native" methodologies that utilize embodiment, spatial interaction, and presence as fundamental learning mechanisms (Rodolico & Hirsu, 2023). Advancing these frameworks necessitates a thorough examination of educators' technology pedagogical content knowledge and their evolution from initial experimentation to enduring pedagogical reasoning. Affective learning continues to be inadequately theorized. Although VR has demonstrated its capacity to facilitate perspective-taking, subsequent research should investigate additional elements of empathy, such as empathic concern and emotional engagement, especially within disciplines like history, psychology, and teacher education (Mulders et al., 2025). In professional training contexts, researchers further advocate incorporating complex, high-pressure scenarios that accurately represent real-world practice, including multitasking and time constraints (Johansen et al., 2025).

3.5.3 Technological Affordances and User Experience Optimization

In terms of technology, the literature shows various fields that need to be advanced. Present VR systems tend to focus on single, game-based learning, and the future is likely to promote collaborative and social learning with real-time connections with peers and instructors (Ferguson et al., 2025; Hammouda et al., 2025; Rossoni et al., 2024). Such “social VR” spaces would greatly improve communication, collaboration and knowledge co-creation. Emerging affordances, such as embodiment, navigability, sense-ability, and create-ability, necessitate a systematic examination to elucidate the impact of specific design features across many contexts (Di Natale, Repetto, et al., 2024). It is also emphasized by scholars that there is a need to develop adaptive and personalized learning systems that should adapt information using real-time data to tailor the required information to the needs and performance trajectories of the individual learners (Hammouda et al., 2025; Sandoval et al., 2025). The physical comfort and usability are still viable barriers. Further studies should focus on reducing the cyber sickness with the use of variable field of view, different movement speed, and user customizations on interface (Luke et al., 2024). The incorporation of multisensory and haptic feedback is also regarded as a potential direction in the improvement of realism and the sense of experience. (Crogman et al., 2025). Design considerations concerning graphical realism also need attention, as too lifelike avatars may trigger discomfort associated with the “uncanny valley,” thereby decreasing the training efficacy (Sandoval et al., 2025).

3.5.4 Accessibility, Inclusivity, and Institutional Readiness

Equity-related challenges constitute another major research gap. Affordable, open-access VR platforms are few, especially in resource-limited areas, hindering wider adoption (Hammouda et al., 2025). Subsequent research should investigate cost–benefit models and economic development tools to assist instructional designers in developing flexible learning environments (Ferguson et al., 2025). Learner inclusivity of disabled students is a poorly explored concept, even though VR could help with transforming learning into an assistive, personalized experience. It needs to be carefully studied how adaptive technologies can enhance the level of access and participation by the different groups of people, e.g., corrective lenses or custom interfaces (Crogman et al., 2025; Ferguson et al., 2025). The institutional factors are also important. The alignment of students, instructors and learning environments is the key to success in the implementation, which can be referred as the “online learning triad” (Ferguson et al., 2025). Subsequent research should explore educator training, technical support Frameworks, and expectation-confirmation models that compare pre-adoption assumptions with post-implementation experiences (Di Natale, Repetto, et al., 2024; Luke et al., 2024)

3.5.5 Emerging Domains and Future Applications

Finally, the research literature recommends expanding VR research into developing fields such as human-centred systems, Industry 5.0, and sustainable energy management to better match education with the changing demands of the workforce (Anjos et al., 2024). Expanding application areas, alongside rigorous empirical validation, will be essential for positioning VR as a mature educational technology rather than a transient innovation.

4. Limitations of the study

Despite the fact that this review presents an overall account of recent changes in VR-supported education, a number of limitations have to be admitted. To begin with, literature search was restricted to those studies that were included in the Scopus database which might have excluded other studies that could be found in other academic databases. Second, the review was restricted by studies that were published in 2023-2025 to think of the latest achievements in immersive learning technologies. Although this methodology emphasizes recent research trends, other preceding study foundations were not factored in the study. Moreover, most of the studies under review used somewhat small sample sizes and did not assess learning outcomes over a long period, which can be a limitation to the generalisability of the reported results. The research limitations could be resolved in future by using more databases, a wider range of time and a larger sample of empirical findings to create a more detailed account of VR-based educational practices.

4.1 Conclusion

This literature review has assessed the recent trends in VR-based education between 2023 and 2025 focusing on the patterns of publications, results of learning, implementation issues, and the developmental patterns of research. Our findings can be interpreted to show that VR is moving beyond an innovative teaching tool to an educational medium of pedagogical importance, particularly in higher education and professional learning. Studies indicate that VR has been proven to enhance student engagement, emotional engagement, and acquisition of skills through the use of immersive and experience learning environments, therefore, leading to affective, cognitive, and psychomotor effects. However, a sustainable integration is limited by financial constraints, technical volatility, physical suffering, cognitive overload and lack of teacher preparation. These issues show that the effectiveness of VR does not only depend on the level of technological expertise, but also on the institutional readiness and teaching cohesion. The future work in VR is recommended to focus on longitudinal studies, large and more diverse samples, and objective performance measures to enhance evidence of the transfer of learning in the long term. VR has a great potential to become a scaled and radical component of the contemporary education through joint research, practice, and policy.

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Authors’ Contributions

VSAG: writing of the original draft, visualisation, conceptualisation, and figure preparation.
KC: provided guidance, editing, validation, supervision and corrections throughout the manuscript preparation
MR, SCS,SB and KE : editing, validation, supervision and corrections

Data availability

The authors declare that the data supporting the findings of this study are available within the article

Declarations

Competing interests

The authors declare that they have no competing interests.

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