Virtual Reality Trends as a Tool for Science Learning Revolution in the 21st Century: A Systematic Review

Arie Wahyu Prananta[1], Ruth Rize Paas Megahati S[2], Sudirman[3*], Liza Yuliana[4]

[1] Faculty of Social Sciences and Cultural Sciences, Universitas Trunojoyo Madura, Madura, Indonesia.
[2] Aquaculture Study Program, Universitas Nahdlatul Ulama Sumatera Barat, Padang, Indonesia.
[3] Department of Physics Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Alauddin, Makassar, Indonesia.
[4] Digital Business Study Program, Universitas Nahdlatul Ulama Sumatera Barat, Padang, Indonesia.

Abstract: VR educational multimedia systems have demonstrated their ability to improve teaching and learning efficiency through the provision of visual and interactive elements that accommodate a variety of learning preferences. This study aims to analyze and explore various research publications that investigate the use of virtual reality as a tool for the educational revolution in higher education. The research method used is a systematic literature review (SLR). The stages of this study include formulating research questions, searching for articles according to the research theme, identifying articles, screening articles, selecting potential articles, analyzing and synthesizing qualitative findings, and preparing a research report. The study yielded 21 potential articles that reflect the most recent research findings. The study's findings indicate that VR has the potential to revolutionize higher education by offering immersive learning experiences that captivate students in ways that conventional approaches cannot. This study highlights the growing interest in the application of VR technology in educational settings. The implications of this study emphasize the role of VR as a tool for the educational revolution in higher education, while also highlighting the need for careful implementation, ongoing research, and investment in technology and training to maximize its benefits.

Keywords: Education revolution; Emerging technologies; Higher education; Virtual reality

Introduction

VR revolutionizes education by establishing immersive, multisensory learning environments that enrich students' comprehension of intricate topics. The use of VR enables a more profound interaction with subject matter that conventional teaching approaches sometimes find challenging to tackle, particularly in higher education environments characterized by the prevalence of abstract ideas. According to Kotov et al. (2024) and Akbar et al. (2024), the utilization of VR enables a more profound interaction with the subject matter. This is consistent with the constructivist learning theory, which highlights the need for students to actively build their understanding through experiential learning processes (Pramanik, 2024). Furthermore, VR educational multimedia systems have demonstrated their ability to enhance the efficiency of teaching and learning by providing visual and interactive elements that accommodate various learning preferences (Kapoor & Kalia, 2024). The research outlines various applications of VR specifically designed for educational goals, highlighting its ability to enhance learning and understanding beyond mere training simulations. As educators further investigate the potential of VR, it becomes evident that this technology not only enhances

the educational experience but also promotes the formation of more precise cognitive representations of intricate systems and processes (Shalender et al., 2024).

VR is emerging as a transformative educational tool, enhancing engagement and understanding through immersive experiences. By creating interactive environments, VR allows students to explore complex concepts in a way that traditional methods cannot achieve. VR facilitates multisensory interaction, making learning more engaging and effective. This active learning approach helps students grasp difficult subjects, particularly in science, by visualizing abstract concepts in a three-dimensional space. Applications of VR range from virtual museum visits to scientific simulations, stimulating curiosity and creativity among students (Ramos & Júnior, 2024). Various educational levels and countries are integrating VR, demonstrating its versatility. For instance, the USA, Italy, and Morocco have successfully implemented VR in their primary schools, high schools, and universities (Sala & Sala 2005). In addition, VR is also used in various courses, such as mathematics, biology, chemistry, history, engineering, and sports. The technology supports different learning styles, making it a valuable resource for diverse classrooms (Carbonara, 2005). The integration of VR into educational frameworks holds significant promise for enhancing student engagement and comprehension, paving the way for innovative teaching methodologies in higher education. (Arora, 2024).

VR is becoming more acknowledged as a revolutionary instrument in higher education, augmenting both the quality of instruction and the learning experiences. Research demonstrates that simulation-based instructional multimedia systems enhance learning by establishing immersive environments that closely mirror real life. This makes it easier for students from a wide range of backgrounds, such as nursing, business, and sports, to comprehend complex topics (Fabris et al., 2019; Susanto et al., 2023). The use of VR technology not only facilitates methodological change in educational practices but also generates captivating and interactive learning experiences, which are critical for promoting profound comprehension. (González Izard et al., 2020). Additionally, using virtual learning environments (VLEs) along with VR technologies opens up new ways to learn that are dynamic, flexible, and individualized, going beyond the limits of traditional ways of teaching (Omieno et al., 2013). As academic institutions further investigate these cutting-edge technologies, the capacity of VR to transform higher education becomes more apparent, facilitating more efficient and captivating learning experiences that equip students for real-life obstacles. According to studies by Young et al. (2020) and Shynatay et al. (2023), VR has the potential to

significantly transform higher education. Therefore, integrating VR into higher education not only enhances the process of acquiring knowledge but also aligns educational methods with the needs of contemporary society.
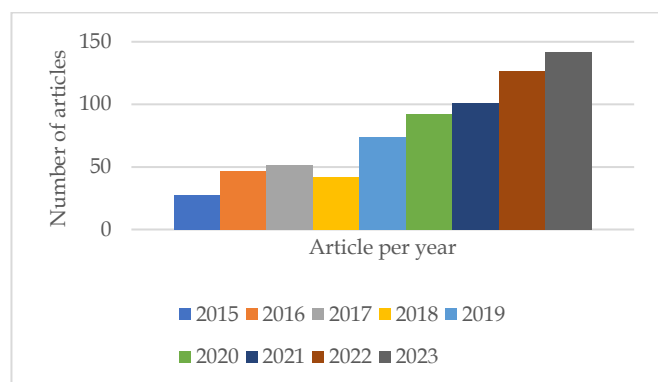
Several researchers have previously studied VR as a tool to revolutionize education, including Yildirim (2024), who found that it enhances athletes' skill learning to acquire and refine their talents in a regulated environment, offering beneficial outcomes for individuals facing physical constraints. Furthermore, VR has the potential to enhance perceptual-cognitive abilities, allowing players to more effectively understand and respond to dynamic learning situations, improving their overall performance (Kang & Kang, 2019). By highlighting context-dependent learning and decision-making, which are essential for students who must adapt to changing situations, the ecological dynamics framework facilitates the use of VR in learning (Zhang & Tsai, 2021). In addition, VR provides an important function in the injury rehabilitation process by offering engaging activities that enhance recovery while maintaining motivation and engagement (Pastel et al., 2023). VR is a powerful tool for educators to create new teaching approaches that facilitate skill acquisition and foster inclusivity in learning. This, in turn, increases the effectiveness and engagement of educational experiences (Geisen et al., 2023). Overall, VR in courses facilitates skill development and encourages a comprehensive approach among students, making it a powerful tool in this domain (Lima et al., 2022; Matitaputty et al., 2024). Previous research suggests that no systematic review has examined virtual reality as a tool for the educational revolution, particularly in higher education. This study aims to analyze and explore various research publications investigating virtual reality as a tool for the educational revolution in higher education. This study aims to address the designed research questions: What is the role of VR in the field of education? What role does VR play in the educational revolution? How is VR a tool for the educational revolution in higher education?

Method

Data Source

The first data source is the SLR research method, which aims to analyze, explore, identify, interpret, and evaluate the results of searching for articles that align with the formulation of research questions. This study's research stages include formulating research questions, searching for articles according to the research theme (Publish or Perish application), identifying articles, filtering articles, selecting potential articles (PRISMA diagram application), analyzing and synthesizing

findings qualitatively, and preparing research reports. We conducted article searches on three databases, namely Scopus, Crossref, and Google Scholar, covering the period from 2015 to 2023 (Figure 1). We conducted literature searches using the keywords VR as a tool for education, emerging technologies, education revolution, and higher education.
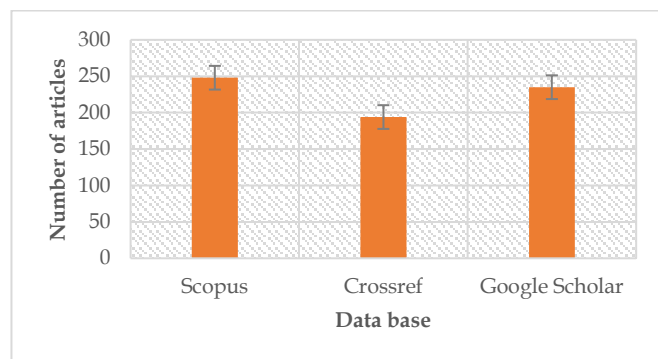

Figure 1. Distribution of literature year base publications

Figure 1 illustrates the distribution of literature year-based publications, revealing that we collected 677 articles from 2015 to 2023. The number of articles published varies from 2015 to 2023, namely 28, 47, 52, 42, 74, 92, 101, 127, and 142.
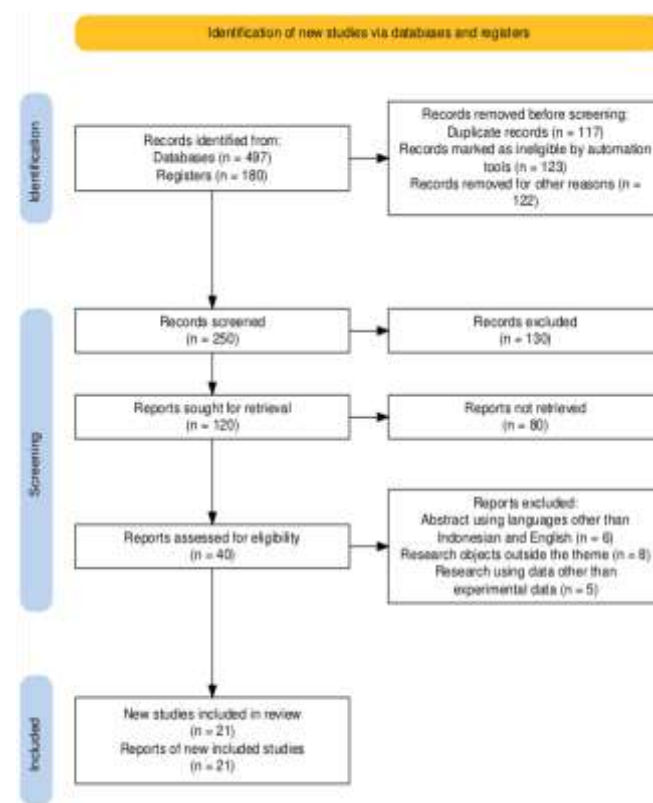
Extraction and Analysis

The present investigation involved the extraction of 667 articles from the Scopus, Crossref, and Google Scholar databases. We harvested 248, 194, and 235 articles from the Scopus, Crossref, and Google Scholar databases (Figure 2).

Figure 2. The database yielded the number of articles

Next, we selected 667 potential articles using the Preferred Reporting Items. In the PRISMA flowchart, there are four stages to obtaining potential articles, namely article selection, identification, screening, and inclusion. Haddaway et al. (2022) developed the

Preferred Reporting Items for Systematic Reviews (PRISMA) flowchart (Figure 3). At the identification stage, the records identified from the database and register were 497 and 180. We recorded 117 articles as duplicates, marked 123 articles as ineligible, and removed 122 articles for other reasons, leaving 250 articles for the screening stage. During the screening stage, we excluded 130 articles, did not retrieve 80 articles, and excluded a further 40 reports for various reasons. After including new research reports, we selected a total of 21 potential articles for inclusion in the review literature at the final inclusion stage. The PRISMA flowchart briefly describes how researchers identify, assess, and integrate research findings in a systematic review. The PRISMA flowchart explains the process of selecting studies for review and the rationale behind certain studies' exclusion.

Figure 3. PRISMA flowchart

We selected potential articles based on their title, abstract, and full text, adhering to specific inclusion and exclusion criteria (Table 1). Defined factors, known as inclusion criteria, were used to select articles for inclusion in a review. On the other hand, we employ exclusion criteria to eliminate articles that do not align with the study objectives.

Table 1. Presents the Inclusion and Exclusion Criteria

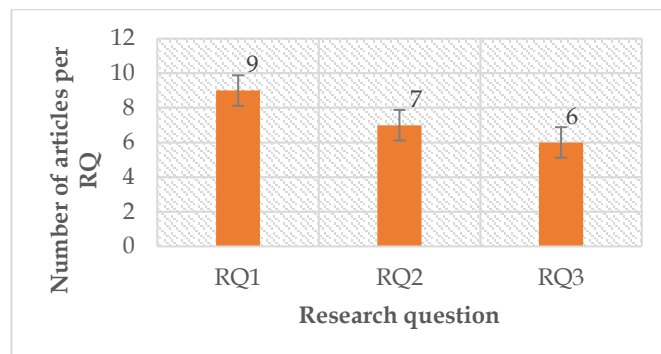| Inclusion criteria	Exclusion criteria
Year of publication between 2015 and 2023	Year of publication outside the range between 2015 and 2023
The research subject studied is VR as a tool for the educational revolution in higher education.	The research subject studied other things than VR as a tool for the educational revolution in higher education.
Research written in English or Indonesian	Research written in languages other than English and Indonesian
Research using quantitative data obtained from experimental results	Research using data other than experimental data
Research discussing VR, VR as a tool for the educational revolution, and VR as a tool for the educational revolution in higher education are not the main themes.	Research discussing VR, VR as a tool for the educational revolution, and VR as a tool for the educational revolution in higher education as the main themes are not the main themes.
Research published by international and national publishers in one of three databases Scopus, Crossref, and Google Scholar, with a Digital Object Identifier (DOI) or an ISSN	Research published by international or national publishers outside the inclusion criteria
Research using quantitative methods such as descriptive surveys, experiments, or a mix of both.	The research did not use quantitative methods such as descriptive surveys, experiments, or a mix of both.

Synthesis of Data

We categorized 21 potential articles into three groups based on the research question (Figure 3).

RQ1 (9 articles): What is the role of virtual reality (VR) in the field of education?

RQ2 (7 articles): What role does VR play in the educational revolution?

RQ3 (5 articles): How is VR a tool for the educational revolution in higher education?

Figure 4. Number of articles based on database

We chose a narrative synthesis methodology to meticulously examine all the data from the included studies, considering the restricted number of studies and the lack of quantitative meta-analysis, even though we employed multiple study designs.

We identified articles based on the primary author, abstract summary, results, and conclusions. We subsequently carried out peer review and focus group discussions to evaluate the quality of all papers.

Results and Discussion

We gathered and reviewed 21 potential articles to address the research questions established at the beginning of the study. Tables 2, 3, and 4 summarize the findings from the systematic review.

RQ1: What is the Role of VR in the Education Field?

Evidence suggests that VR can enhance student involvement, knowledge retention, and critical thinking abilities by providing practical experiences and simulating real-life situations (Table 2). Applications span a wide spectrum, from the exploration of historical places to the execution of scientific experiments, therefore rendering abstract ideas more concrete (Begum, 2024). Although VR has significant promise in the field of education, it is crucial to tackle obstacles such as cost, accessibility, and technological constraints to achieve broad acceptance (Maheshwari et al., 2020).

Table 2. The Role of VR in Education

Author	Abstract summary	Result	Conclusion
Sharma et al. (2023)	VR can revolutionize conventional educational approaches and enhance the process of teaching and learning.	The review findings indicate a substantial increase in the use of VR in education over the past eight years. Furthermore, VR can revolutionize conventional educational approaches and enhance student learning capabilities.	The integration of VR in education can have both positive and negative effects on students' well-being and academic performance. The potential of VR is to revolutionize and improve conventional educational methodologies and instructional techniques.

Author	Abstract summary	Result	Conclusion
Gan et al. (2023)	We are analyzing the progressive development of VR education, which has beneficial impacts in several domains.	I have analyzed the beneficial impacts of VR on teaching.	We are evaluating the beneficial impacts of VR on education.
	An investigation into the potential of virtual reality technology to enhance educational experiences is underway.	The field of education is investigating the potential and feasibility of VR.	We are investigating advanced virtual reality technologies for future educational applications.
Lin et al. (2023)	VR technologies are being used in education for various purposes such as games, art, and political education.	VR finds applications in educational games, art, and political education.	VR enriches education by including gaming, art, and political elements.
	The text emphasizes the function of virtual reality in art education and the instruction of concepts.	Virtual reality improves the teaching of conceptual knowledge, art education, and ideological education.	VR technology has a substantial impact on art instruction.
Melinda & Widjaja (2022)	VR allows users to engage in interactions within a simulated environment.	The effectiveness of VR in education stems from its ability to provide immersive 3D experiences.	The effectiveness of VR in education stems from its ability to provide immersive 3D experiences.
	VR is highly efficient in the realm of education.	In VR, users can view objects from many perspectives.	In VR, users can view objects from many perspectives.
Zhang, (2022)	VR technology in education improves learning by providing lifelike simulations.	VR technology.	VR technology has immense pedagogical potential.
	An immersive reality technology enhances student involvement and improves instructional efficacy.	VR facilitates enhanced student engagement and instructional efficacy.	It improves the efficacy of instruction and student involvement.
Mohring & Brendel (2021)	VR allows for immersive experiences that have the potential to be long-lasting and enhance learning.	This study investigates how to VR field trips into educational settings.	Immersive virtual reality field trips enrich sensory-based and conscientious geographical instruction.
	The application of VR in education necessitates careful contemplation of physical and emotional aspects.	This research highlights the need to engage in critical analysis of the utilization of VR.	Engaging in critical analysis of the body and emotions increases awareness during the learning process.
Alrababah & Shorman (2021)	VR is very efficient in teaching STEM courses since it improves both engagement and comprehension.	The efficacy of VR in the instruction of STEM disciplines is noteworthy.	The efficacy of VR in the instruction of STEM disciplines is noteworthy.
	The present study centers on the impact of VR on biology and medicine courses.	VR has beneficial impacts on the acquisition of knowledge in biology and	VR has a positive impact on the acquisition of knowledge in biology and
AlFarsi & Mohd Yusof (2020)	VR applications are gaining traction in the field of education.	VR applications are gaining traction in the field of education.	VR has found applications in diverse industries.
	VR allows for instruction in virtualized settings.	VR facilitates instruction in virtual learning.	The education field holds remarkable promise for virtual reality.

Author	Abstract summary	Result	Conclusion
Alshammari, (2019)	VR enriches students' intellectual development in several domains.	VR improves collaborative/cooperative learning, creative learning, problem-based learning, and role acting.	VR can improve instruction and optimize students' learning.
	VR provides distinct opportunities for learning and instruction.	VR offers distinct possibilities for augmenting instruction and students' acquisition of knowledge.	VR technology offers distinct prospects and obstacles.

The results of the review of 9 potential articles included in RQ1 show that VR is becoming recognized as a potent instrument in the field of education, providing immersive and interactive experiences that augment student learning in many academic fields (Table 2). According to Alshammari (2019), Tats et al. (2024), VR facilitates collaborative learning, creativity, problem-solving, and role-playing, therefore enhancing the overall engagement and enjoyment of education. Empirical evidence suggests that it can enhance academic achievement, promote analytical thinking, and enhance the retention of information (Vats & Joshi, 2024; Sharma et al., 2023). VR applications encompass a wide range of educational domains, such as general, engineering, and health-related academic disciplines (Kamińska et al., 2019). Despite its advantages, we must resolve obstacles like exorbitant expenses, ease of access, and technical constraints to achieve widespread acceptance (Alshammari, 2019; Animashaun et al., 2024). The ongoing progress of VR technology offers prospects for revolutionizing conventional teaching approaches and functioning as a supplementary instrument to augment learning experiences (Maheshwari et al., 2020).

VR revolutionizes education by establishing immersive, multisensory learning environments that enrich students' comprehension of intricate topics. By engaging all human senses, virtual reality enhances interaction with content, especially in disciplines such as physics and mathematics, where conventional teaching approaches frequently prove inadequate (Kotov et al., 2024; Pramanik, 2024). This is consistent with the constructivist learning theory, which highlights the need for students to actively build their understanding through experiential learning processes (Ardiny & Khanmirza, 2018). An exemplary use of VR in the field of education is the implementation of Studies, a multi-user collaborative virtual environment specifically created to facilitate interactive learning. This platform exemplifies the ability of VR to successfully communicate intricate ideas, such as basic three-dimensional geometry, by enabling students to visually see and control abstract models in a dynamic environment (Leong et al., 2023). In general, VR not only inspires and enhances students' comprehension but also offers novel possibilities for educators to instruct intricate systems and processes, therefore transforming the educational environment.

RQ2: What role does VR play as a tool in the educational revolution?

VR is becoming recognized as a revolutionary instrument in the field of education, augmenting immersion and comprehension by providing engaging experiences. VR enables students to investigate intricate ideas and historical histories in ways that conventional approaches are unable to achieve by creating interactive worlds (Table 3).

Table 3. VR a Tool for the Educational Revolution

Author	Abstract summary	Result	Conclusion
Ong et al. (2023)	Analyzing the impact of IR4.0 on VR as a tool for the educational revolution in preventive health education.	The program emphasizes the use of VR as a tool in preventative health education. These are illustrative examples of digital technologies in the healthcare environment.	VR is being used as a tool for the educational revolution. Preventive health education is emphasized.
	Illustrative examples of augmented reality or VR assistance in health science education.		It provides analysis and recommendations for forthcoming digital technologies.
Araiza-Alba et al. (2021)	VR is a highly promising educational tool for the educational revolution that can actively involve	VR is a very promising tool for augmenting problem-solving abilities in children, resulting in elevated rates of success,	VR plays a crucial role in the educational revolution, aiding in the acquisition and refinement of problem-solving abilities. VR's

Author	Abstract summary	Result	Conclusion
	youngsters and enhance their problem-solving skills, therefore suggesting its potential for wider implementation in educational environments.	heightened perseverance, and more streamlined problem-solving approaches.	effectiveness stems from its ability to captivate users and present information in a lifelike environment, thereby enhancing cognitive processing and knowledge transfer.
Au & Lee, (2017)	VR is a unique technology that offers interactive and immersive learning experiences to address various problems in education.	VR, as a tool in education, emphasizes its potential to increase engagement, foster empathy, and support constructivist learning, while also calling for careful consideration in its implementation.	VR is a tool in education, highlighting its potential to transform the learning experience while emphasizing the need for sound pedagogy and ongoing research to maximize its benefits.
Figueiredo et al. (2021)	The field of informatics, computer technology, virtual reality, and educational innovation is constantly changing. The proposal aims to integrate VR into education as part of a social innovation experiment.	We have a rough proposal to implement virtual reality in primary schools. Engaging public school instructors in a VR integration experiment	VR: a tool for the educational revolution in the education field.
Izard & Muñoz, (2017)	VR a tool for the educational revolution that utilizes immersive virtual reality technology. The purpose is to educate pupils about the environment and foster ethical values.	VR a tool for the educational revolution designed for environmental education, including interactive simulations and assessments. It encourages students to be ethically committed and actively explore their knowledge.	It is imperative to keep teachers informed about emerging applications and technologies. VR a tool for the educational revolution This enhances education by offering immersive experiences and simulations. The program strives to foster ethical dedication and engaged learning among pupils.
Sulaiman et al. (2019)	VR, a tool for the educational revolution, requires improvement in terms of self-learning and interface familiarity.	Enhancements to VR applications' self-learning and interaction familiarity are required. We observed statistically insignificant differences between gender and computer gaming.	There is an improvement in terms of self-learning through the use of VR as a tool for the educational revolution.
Choi et al. (2016)	VR represents the upcoming frontier of communication. Students are motivated to integrate academic instruction with immersive technology tools.	By utilizing immersive VR technology tools, educators can motivate students. Virtual reality enriches the instructional experience for aspiring industry executives.	VR is a cutting-edge educational technology tool. Educators can motivate pupils in novel ways.

The results of a review of seven articles about VR as a tool for the educational revolution revealed several new findings (Table 3), including that VR has the potential to revolutionize education by providing immersive and multisensory learning experiences that enhance understanding of complex subjects. In contrast to conventional teaching approaches, VR actively involves all human senses, enabling students to investigate and engage with three-dimensional (3D) depictions of ideas. This is especially advantageous for abstract and non-intuitive content. According to Bassil et al. (2023) and Choi et al. (2016), this approach is

particularly beneficial for abstract and non-intuitive content. By transforming passive content consumption into active, experiential learning, this immersive learning strategy promotes deeper cognitive engagement and motivation (Sulaiman et al., 2019). Furthermore, VR enables students to develop accurate mental representations of intricate systems through direct experience in a safe and controlled setting, aligning with constructivist learning philosophies. According to Araiza-Alba et al. (2021) and Geurts et al. (2023), VR enables students to develop accurate mental representations of intricate systems through direct experience in a safe and controlled setting, aligning with constructivist learning philosophies. Vicher and similar programs exemplify the integration of VR into higher education, offering distinctive educational experiences that conventional approaches are unable to provide (Figueiredo et al., 2021). As educators increasingly embrace VR technologies, they access novel possibilities for teaching and learning, ultimately transforming the educational environment to more effectively equip students for the intricacies of the contemporary world (Serin, 2020). Therefore, VR serves as a revolutionary tool in educational development, augmenting both involvement and comprehension in diverse fields of study.

VR greatly enhances practical learning experiences in education by creating immersive worlds that engage many senses and promote a deeper comprehension of complex subjects. VR allows students to realistically engage with instructional material through the simulation of real-life situations, fostering active learning and involvement. According to Mallek et al. (2024) and Kaul et al. (2024), virtual reality enables students to engage with instructional material realistically through the simulation of real-life situations, fostering active learning and involvement. This multisensory technique is very efficient in facilitating students' development of accurate mental representations of non-intuitive content and intricate systems, which conventional teaching approaches typically find challenging to communicate (Rajassekharan et al., 2024; Ramos & Júnior, 2024). Moreover, VR's capacity to stimulate all human senses is essential for improving learning outcomes, as it transcends just intellectual involvement to cultivate emotional and sensory connections with the subject matter (Sudharson et al., 2024). This immersive learning environment serves as a source of motivation for students, as well as fostering their exploration and comprehension of complex processes in a way that is both captivating and educationally potent (Krajčovič et al., 2022). In general, using VR in educational environments signifies a revolutionary method of acquiring knowledge and enhancing the accessibility and understanding of intricate topics for younger learners.

RQ3: How does VR serve as a tool for the educational revolution in higher education?

The use of VR is becoming increasingly prominent in higher education, fundamentally changing the approaches to teaching and learning. The creation of immersive worlds using VR serves to augment student engagement and comprehension of intricate ideas, therefore rendering education more interactive and personalized (Table 4). VR's potential as a tool for the educational revolution in higher education lies in its ability to offer immersive learning experiences that captivate students in ways that conventional approaches are unable to achieve (Table 4). VR augments students' comprehension of intricate topics, especially in disciplines such as science where conventional teaching approaches are sometimes inadequate, by generating multimodal settings that engage all human senses (Faron & Kabashi, 2023; Sun et al., 2019).

Table 4. VR a Tool for the Educational Revolution in Higher Education

Author	Abstract summary	Result	Conclusion
Faron & Kabashi (2023)	Institutions of higher education use virtual and digital simulations. Higher education uses VR, a cutting-edge technology, to enhance the development of skills and abilities.	This work showcases the application of VR to drive the educational revolution in higher education. It aims to enable transformation in competencies, abilities, and attitudes.	Higher education uses VR simulation as a sophisticated tool to enhance skills and competencies, enabling competency transformation.
Jin et al. (2022)	VR has the potential to significantly impact pedagogical methodologies in higher education.	We've identified stakeholders for the implementation of VR in higher education.	We're segmenting stakeholders for the implementation of VR in higher education.
	Stakeholders' opinions and considerations for VR	We have identified the obstacles and potential advantages of using VR in university classroom applications.	We discuss the main challenges and potential benefits of VR in educational settings.

Author	Abstract summary	Result	Conclusion
Maham arowi et al. (2022)	adoption: a qualitative study.		
	We are revolutionizing interior design education using interactive VR technologies.	A VR educational tool enhances the learning experience for students studying interior design.	VR technologies revolutionize the learning experience for interior design students.
	Research indicates that VR enhances students' comprehension of instruction.	According to survey findings, students perceive virtual reality as useful for understanding lessons.	Students perceive VR as more effective and more accessible for comprehending design lessons.
Sun et al. (2019)	A VR evaluation tool for higher education was developed.	Students like VR-based tools over traditional evaluation tools.	Students, especially those from underrepresented minority groups, favor VR learners.
	VR is the preferred tool among underrepresented minority students.	Interactive VR technology enhances students' sense of engagement.	Virtual reality technology serves to augment educational technologies and serious games.
Yang, (2018)	In higher education institutions, VR technology improves the quality of education and instruction.	In higher education institutions, transform the field of education and instruction.	Advanced virtual reality technology transforms the quality of instruction in institutions.
	VR technology transforms education and enhances its quality.	Enhance the quality of instruction with distinctive allure and liveliness.	Significantly enhances and influences future education.

This is consistent with the constructivist learning theory, which highlights the need for students to actively build their knowledge through immersive processes (Yang, 2018). Moreover, virtual reality enables students to investigate and operate complex systems in a safe and controlled environment, allowing hands-on interaction with educational information (Mahamarowi et al., 2022). The article scrutinizes various types of VR applications specifically designed for educational purposes, prioritizing the enhancement of learning over mere training (Jin et al., 2022).

The growing adoption of VR technologies by educators has the potential to establish dynamic learning environments that effectively inspire and engage students, thereby revolutionizing the higher education educational sector (Pinter et al., 2023; Lara-Lara et al., 2023). This transition not only improves understanding but also equips students for the practical implementation of their knowledge, demonstrating notable progress in instructional approaches.

VR integration in higher education greatly improves student engagement by offering immersive and interactive learning opportunities. Research shows that VR promotes cognitive involvement, especially in the fields of adaptive sports (Yildirim, 2024). It does so by utilizing VR technology to replicate sports training, minimize injuries, and enhance performance (Liu & Tian, 2024). Diverse VR applications, including simulations and virtual laboratories, facilitate experiential learning, which is essential for cultivating critical thinking and collaboration abilities in students (Goi, 2024). Moreover, comparative research indicates that VR has the potential to enhance academic involvement in engineering fields by enabling students to address practical challenges within a virtual environment (Yang, 2018). Nevertheless, there are still obstacles to overcome, including the requirement for impactful lesson material and instructor readiness, as well as some limitations in reading comprehension when using virtual reality in comparison to conventional approaches (Çoban et al., 2024). Although VR offers some benefits, it is crucial to acknowledge its constraints, such as restricted accessibility and the need for specialized training for both students and teachers (Pramanik, 2024).

The constraints of VR as a disruptive instrument for educational transformation in higher education are manifold, including theoretical, practical, and infrastructural obstacles. Theoretical complexities stem from the intrinsic challenge of adequately stimulating specific senses in virtual reality settings, thereby impeding the overall educational experience (Cabrera-Duffaut et al., 2024). However, there are some problems with how virtual reality works, such as making it challenging to stimulate senses like smell, taste, and touch (Ghinea et al., 2012). This further makes using virtual reality in schools more difficult. Furthermore, the issue of cost barriers is a significant challenge because the exorbitant costs associated with virtual reality technology limit its availability for several educational institutions, thereby impeding its successful integration (Akbar & Djakariah, 2024; Refmidawati, 2023). Indeed, the requirement for strong technological infrastructure, encompassing sophisticated hardware, software, and

reliable internet connection, presents other obstacles that institutions must surmount to effectively employ virtual reality in education (Indriati, 2023). Collectively, these constraints emphasize the intricacies associated with incorporating VR into higher education. This implies that although VR can improve learning experiences, substantial obstacles need to be overcome to fully leverage its advantages.

Conclusion

The study highlights a growing interest in the application of VR technologies within educational settings. The extraction of 667 articles from various databases demonstrates a robust body of research on the topic. The research identifies multiple questions regarding VR's impact on education. Specifically, it categorizes the literature into three main research questions, with a focus on VR's role in education and its potential as a revolutionary tool in higher education. The authors employed a narrative synthesis methodology to analyze the data, which was necessary due to the limited number of studies and the absence of quantitative meta-analysis. This approach allowed for a qualitative assessment of the findings from the selected articles. The paper emphasizes the importance of quality in research. We conducted peer review and focus group discussions to evaluate the quality of the included studies, ensuring that the conclusions were based on reliable and valid research. The study utilized specific exclusion criteria to filter out articles that did not align with the research objectives. This rigorous selection process helped to maintain the relevance and quality of the reviewed literature. The analysis reveals gaps in the existing literature, particularly in the quantitative assessment of VR's effectiveness in educational settings. The authors note that while qualitative insights are valuable, there is a need for more quantitative studies to substantiate the claims made about VR's educational benefits. The paper suggests that future research should focus on exploring the integration of artificial intelligence (AI) with VR in education, as well as conducting more extensive studies that can provide quantitative data to support the qualitative findings. The paper concludes that VR has promising potential to transform higher education, but further research is necessary to fully understand its impact and effectiveness. The findings underscore the necessity for a balanced approach that includes both qualitative and quantitative research methodologies. The implications of this research highlight VR as a tool for the educational revolution in higher education, while also emphasizing the need for careful implementation, ongoing research, and investment in technology and training to maximize its benefits. We would like to express our gratitude to the head of the study program who granted permission for this research, as well as all other parties involved in its implementation.

Conflicts of Interest
The authors declare that they have no conflict of interest.

References

Akbar, J. S., & Djakariah, D. (2024). Educational Transformation: Using Virtual Reality as a Learning Tool for The Future. *Cognitive Development Journal*, 2(1), 26–31. https://doi.org/10.32585/cognitivedevelopmentjournal.v2i1.32

AlFarsi, G., & Mohd Yusof, A. B. (2020). Virtual Reality Applications in Education Domain. *2020 21st International Arab Conference on Information Technology (ACIT)*, 1–7. https://doi.org/10.1109/ACIT50332.2020.9300056

Alrababah, Z., & Shorman, S. (2021). Review of Effects of the Virtual Reality in Education. In *The Big Data-Driven Digital Economy: Artificial and Computational Intelligence* (Vol. 974, pp. 445–459). Springer International Publishing. https://doi.org/10.1007/978-3-030-73057-4_33

Alshammari, S. H. (2019). The Role of Virtual Reality in Enhancing Students' Learning. *International Journal of Educational Technology and Learning*, 7(1), 1–6. https://doi.org/10.20448/2003.71.1.6

Araiza-Alba, P., Keane, T., Chen, W. S., & Kaufman, J. (2021). Immersive virtual reality as a tool to learn problem-solving skills. *Computers & Education*, 164, 104121. https://doi.org/10.1016/j.compedu.2020.104121

Ardiny, H., & Khanmirza, E. (2018). The Role of AR and VR Technologies in Education Developments: Opportunities and Challenges. *2018 6th RSI International Conference on Robotics and Mechatronics (IcRoM)*, 482–487. https://doi.org/10.1109/ICRoM.2018.8657615

Arora, M. (2024). Virtual Reality in Education: Analyzing the Literature and Bibliometric State of Knowledge. In *Transforming Education with Virtual Reality* (1st ed., pp. 379–402). Wiley. https://doi.org/10.1002/9781394200498.ch22

Au, E. H., & Lee, J. J. (2017). Virtual reality in education: A tool for learning in the experience age. *International Journal of Innovation in Education*, 4(4), 215. https://doi.org/10.1504/IJIIE.2017.091481

Bassil, E., Mehdi, A., Arrigain, S., Schold, J. D., Sedor, J. R., Nally, J. V., O'Toole, J. F., Bierer, S. B., Taliercio, J. J., & Nakhoul, G. (2023). Virtual Nephron: Assessment of a Virtual Reality (VR) Educational Tool: FR-PO065. *Journal of the American Society of Nephrology*, 34(11S), 423–424. https://doi.org/10.1681/ASN.20233411S1423c

Begum, Dr. S. (2024). Virtual Reality In Education: Transforming Learning Environments. *Educational Administration: Theory and Practice*, 8967–8973. https://doi.org/10.53555/kuey.v30i5.4491

Cabrera-Duffaut, A., Pinto-Llorente, A. M., & Iglesias-Rodríguez, A. (2024). Immersive learning platforms: Analyzing virtual reality contribution to competence development in higher education—a systematic literature review. *Frontiers in Education*, 9, 1391560. https://doi.org/10.3389/feduc.2024.1391560

Carbonara, D. (2005). *Technology Literacy Applications in Learning Environments:* IGI Global. https://doi.org/10.4018/978-1-59140-479-8

Chen, J., Fu, Z., Liu, H., & Wang, J. (2023). Effectiveness of Virtual Reality on Learning Engagement: A Meta-Analysis. *International Journal of Web-Based Learning and Teaching Technologies*, 19(1), 1–14. https://doi.org/10.4018/IJWLTT.334849

Choi, D. H., Dailey-Hebert, A., & Simmons Estes, J. (Eds.). (2016). *Emerging Tools and Applications of Virtual Reality in Education:* IGI Global. https://doi.org/10.4018/978-1-4666-9837-6

Çoban, M., Topuz, A. C., Karabulut, A., & K. F. Chiu, T. (2024). Comparing Realities: A Study on the Impact of Virtual Reality versus Paper-Based Reading on Higher Education Students' Comprehension Skills. *Participatory Educational Research*, 11(4), 19–36. https://doi.org/10.17275/per.24.47.11.4

Fabris, C. P., Rathner, J. A., Fong, A. Y., & Sevigny, C. P. (2019). Virtual Reality in Higher Education. *International Journal of Innovation in Science and Mathematics Education*, 27(8). https://doi.org/10.30722/IJISME.27.08.006

Faron, A., & Kabashi, A. (2023). Virtual Business Simulation as a Tool Fostering Modern Teaching Methods in Higher Education Institutions. *42nd International Conference on Organizational Science Development*, 277–288. https://doi.org/10.18690/um.fov.3.2023.23

Figueiredo, M., Mafalda, R., & Kamensky, A. (2021). Virtual Reality as an Educational Tool for Elementary School. In *Proceedings of IDEAS 2019* (Vol. 198, pp. 261–267). Springer International Publishing. https://doi.org/10.1007/978-3-030-55374-6_26

Gan, X., Hu, L., Wu, S., & Xiao, Y. (2023). Research and Analysis of VR in the Field of Education. *Highlights in Science, Engineering and Technology*, 72, 1126–1133. https://doi.org/10.54097/t94dn648

Geisen, M., Fox, A., & Klatt, S. (2023). VR as an Innovative Learning Tool in Sports Education. *Applied Sciences*, 13(4), 2239. https://doi.org/10.3390/app13042239

Geurts, E., Van Den Bergh, J., & Vanherle, B. (2023). Tool-based Interaction for Precise Manipulation in VR: An Exploratory Study. *Proceedings of the European Conference on Cognitive Ergonomics 2023*, 1–8. https://doi.org/10.1145/3605655.3605677

Ghinea, G., Andres, F., & Gulliver, S. R. (2012). *Multiple Sensorial Media Advances and Applications: New Developments in MulSeMedia*. IGI Global. https://doi.org/10.4018/978-1-60960-821-7

Goi, C. L. (2024). The Impact of VR-Based Learning on Student Engagement and Learning Outcomes in Higher Education: In *Practice, Progress, and Proficiency in Sustainability* (pp. 207–223). IGI Global. https://doi.org/10.4018/978-1-6684-9859-0.ch012

González Izard, S., & Ventura Muñoz, S. (2017). *Educational Virtual Reality Tool To Teach Students To Respect Environment*. https://doi.org/10.21125/edulearn.2017.1479

González Izard, S., Vivo Vicent, C., Juanes Méndez, J. A., & Palau, R. (2020). Virtual Reality In Higher Education: An Experience With Medical Students: Research into how Virtual Reality can be used as a powerful training tool for medicine students. *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality*, 414–421. https://doi.org/10.1145/3434780.3436539

Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimized digital transparency and Open Synthesis. *Campbell Systematic Reviews*, 18(2), e1230. https://doi.org/10.1002/cl2.1230

Indriati, G. (2023). Using Virtual Reality to Help Teachers Improve Learning: A Review. *Journal of Digital Learning and Distance Education*, 2(6), 635–638. https://doi.org/10.56778/jdlde.v2i6.286

Jin, Q., Liu, Y., Yarosh, S., Han, B., & Qian, F. (2022). How Will VR Enter University Classrooms? Multi-stakeholders Investigation of VR in Higher Education. *CHI Conference on Human Factors in Computing Systems*, 1–17. https://doi.org/10.1145/3491102.3517542

Kamińska, D., Sapiński, T., Wiak, S., Tikk, T., Haamer, R., Avots, E., Helmi, A., Ozcinar, C., & Anbarjafari, G. (2019). Virtual Reality and Its Applications in Education: Survey. *Information*, *10*(10), 318. https://doi.org/10.3390/info10100318

Kang, S., & Kang, S. (2019). The study on the application of virtual reality in adapted physical education. *Cluster Computing*, *22*(S1), 2351–2355. https://doi.org/10.1007/s10586-018-2254-4

Kapoor, S., & Kalia, G. (2024). Role of Virtual Reality in Education: Its Scope, Reach and Effect on Student Behavior. In *Transforming Education with Virtual Reality* (1st ed., pp. 145–164). Wiley. https://doi.org/10.1002/9781394200498.ch9

Kaul, N., & Kumar, C. (2024). Exploring the Landscape of Virtual Reality in Education: A Bibliometric and Thematic Analysis. In *Transforming Education with Virtual Reality* (1st ed., pp. 181–199). Wiley. https://doi.org/10.1002/9781394200498.ch11

Kotov, R., Kryuk, R., & Turov, S. (2024). Prospects for VR Technologies in Education and Social Life. *Virtual Communication and Social Networks*, 162–168. https://doi.org/10.21603/2782-4799-2024-3-2-162-168

Krajčovič, M., Gabajová, G., Matys, M., Furmannová, B., & Dulina, Ľ. (2022). Virtual Reality as an Immersive Teaching Aid to Enhance the Connection between Education and Practice. *Sustainability*, *14*(15), 9580. https://doi.org/10.3390/su14159580

Lara-Lara, F., De La Cruz-Campos, J.-C., Ramos-Navas-Parejo, M., & Berral-Ortiz, B. (2023). Teaching Innovation in Higher Education Through Virtual Reality. In *Ambient Intelligence – Software and Applications – 14th International Symposium on Ambient Intelligence* (Vol. 770, pp. 241–249). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-43461-7_24

Leong, W. Y., Leong, Y. Z., & Leong, W. S. (2023). Virtual reality in education: Case studies and applications. *IET International Conference on Engineering Technologies and Applications (ICETA 2023)*, 186–187. https://doi.org/10.1049/icp.2023.3332

Lima, R., Asif, M., Sousa, H., & Bermúdez I Badia, S. (2022). Adaptive Control of Cardio-respiratory Training in a Virtual Reality Hiking Simulation: A Feasibility Study: *Proceedings of the 15th International Joint Conference on Biomedical Engineering Systems and Technologies*, 91–99. https://doi.org/10.5220/0011004400003123

Lin, Y., You, Y., & Zhou, Z. (2023). Application Of VR In the Field of Education. *Highlights in Science, Engineering and Technology*, *68*, 11–20. https://doi.org/10.54097/hset.v68i.11925

Liu, B., & Tian, D. (2024). Application of VR technology in sports training in colleges and universities. *Applied Mathematics and Nonlinear Sciences*, *9*(1), 20240330. https://doi.org/10.2478/amns-2024-0330

Mahamarowi, N. H., Fazeel, A., Yusoff, N. H. M., & Mustapha, S. (2022). VR Educational Teaching Tools for Viewing 3D View in Interior Design Education at Higher Institution. *2022 Engineering and Technology for Sustainable Architectural and Interior Design Environments (ETSAIDE)*, 1–4. https://doi.org/10.1109/ETSAIDE53569.2022.9906400

Maheshwari, I., & Maheshwari, P. (2020). Effectiveness of Immersive VR in STEM Education. *2020 Seventh International Conference on Information Technology Trends (ITT)*, 7–12. https://doi.org/10.1109/ITT51279.2020.9320779

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

Mardiyah, S. U. K., Setyawan, H., Pavlovic, R., Darmawan, A., Susanto, N., & Kozina, Z. (2024). Management for Strengthening Literacy Learning Culture Physical Education in Secondary School in Indonesia. *Sport Science and Health*, *14*(5), 81-91. https://doi.org/10.7251/SSH24V081M

Matitaputty, J. K., Saputra, N., Judijanto, L., Susanto, N., Hanif, M., Sopacua, J., & Fadli, M. R. (2024). PjBL-based digital history model to improve historical concept skills and historical consciousness. *Journal of Education and Learning (EduLearn)*, *18*(2), 430–440. https://doi.org/10.11591/edulearn.v18i2.21152

Mohring, K., & Brendel, N. (2021). Producing virtual reality (VR) field trips – a concept for a sense-based and mindful geographic education. *Geographica Helvetica*, *76*(3), 369–380. https://doi.org/10.5194/gh-76-369-2021

Omieno, K. K., Wabwoba, F., & Matoke, N. (2013). Virtual Reality in Education: Trends And Issues. *International Journal of Computers & Technology*, *4*(1), 38–43. https://doi.org/10.24297/ijct.v4i1a.3033

Ong, E. T., Pang, Y. J., Talib, C. A., Setiawan, R., Ng, J. H., & Por, F. P. (2023). Industrial Revolution (IR) and Exemplary AR/VR-based Technological Tools in Preventive Health Education. In *Immersive Virtual and Augmented Reality in Healthcare* (1st ed.,

pp. 1–27). CRC Press. https://doi.org/10.1201/9781003340133-1

Pastel, S., Petri, K., Chen, C. H., Wiegand Cáceres, A. M., Stirnatis, M., Nübel, C., Schlotter, L., & Witte, K. (2023). Training in virtual reality enables learning of a complex sports movement. *Virtual Reality*, 27(2), 523–540. https://doi.org/10.1007/s10055-022-00679-7

Pinter, L., Izquierdo, M., & Siddiqui, M. F. H. (2023). Revolutionizing Learning: An Interactive VR Application for Solids of Revolution. *Proceedings of the 7th International Conference on Education and Multimedia Technology*, 35–40. https://doi.org/10.1145/3625704.3625742

Pramanik, S. (2024). Immersive Innovations: Exploring the Use of Virtual and Augmented Reality in Educational Institutions. In *Advances in Higher Education and Professional Development* (pp. 229–243). IGI Global. https://doi.org/10.4018/979-8-3693-2857-6.ch013

Pramanik, S. (2024c). Role of AR and VR in the Context of Technical Education: In *Advances in Medical Education, Research, and Ethics* (pp. 22–33). IGI Global. https://doi.org/10.4018/979-8-3693-5493-3.ch002

Rajassekharan, D., & B., V. (2024). Ubiquitous Learning Experience using VR in Electronic Science Education. *Journal of Trends in Computer Science and Smart Technology*, 6(2), 199–212. https://doi.org/10.36548/jtcsst.2024.2.008

Ramos, R. C., & Júnior, W. L. B. (2024). Realidade Virtual Na Educação Fundamentos, Dispositivos, Aplicações e Inovação no Ensino. *RCMOS - Revista Científica Multidisciplinar O Saber*, 1(1). https://doi.org/10.51473/rcmos.v1i1.2024.540

Refmidawati. (2023). Virtual Reality Media for Fun Learning. *Journal of Digital Learning And Distance Education*, 2(4), 544–547. https://doi.org/10.56778/jdlde.v2i4.79

Serin, H. (2020). Virtual Reality in Education from the Perspective of Teachers. *Revista Amazonia Investiga*, 9(26), 291–303. https://doi.org/10.34069/AI/2020.26.02.33

Shalender, K., Singla, B., & Sharma, S. (2024). VR in Vocational Educational and Training: Conceptual Framework and Adoption Roadmap. In *Transforming Education with Virtual Reality* (1st ed., pp. 201–209). Wiley. https://doi.org/10.1002/9781394200498.ch12

Sharma, M., Kumar, P., & Singh, D. K. (2023). The Role of Virtual Reality in Education: A Comprehensive Review of Research and Application. *2023 1st DMIHER International Conference on Artificial Intelligence in Education and Industry 4.0 (IDICAIEI)*, 1–6. https://doi.org/10.1109/IDICAIEI58380.2023.10406461

Shynatay, G., Shyndaliyev, N., & Erlanova, G. (2023). Virtual reality technology in higher education: An umbrella review of systematic reviews and meta-analyses. *Journal of Educational Sciences*, 74(1). https://doi.org/10.26577/JES.2023.v74.i1.09

Sudharson, D., Malik, R., Sathya, R. R., Vaishali, V., Balavedhaa, S., & Gautham, S. (2024). A Novel Adaptive Framework for Immersive Learning Using VR in Education. In *Transforming Education with Virtual Reality* (1st ed., pp. 1–26). Wiley. https://doi.org/10.1002/9781394200498.ch1

Sulaiman, H., Apandi, S. N., Yusof, A. Mohd., Abdul Latif, R., & Ibrahim, N. (2019). Evaluation of a Virtual Reality (VR) Learning Tool for Fundamental Turbine Engineering Concepts. In *Advances in Visual Informatics* (Vol. 11870, pp. 48–59). Springer International Publishing. https://doi.org/10.1007/978-3-030-34032-2_5

Sun, B., Chikwem, U., & Nyingifa, D. (2019). VRLearner: A Virtual Reality-Based Assessment Tool in Higher Education. *2019 IEEE Conference on Virtual Reality and 3D User Interfaces (VR)*, 1640–1645. https://doi.org/10.1109/VR.2019.8798129

Tafuri, F., Martinez-Roig, R., Susanto, N., Setyawan, H., & Latino, F. (2024). Physically Active Lifestyles within the School Context: Morpho-Physiological and Functional Aspects. *Retos*, 58(2), 48-60. https://doi.org/10.47197/retos.v58.106154

Vats, S., & Joshi, R. (2024). The Impact of Virtual Reality in Education: A Comprehensive Research Study. In *Transfer, Diffusion and Adoption of Next-Generation Digital Technologies* (Vol. 699, pp. 126–136). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-50204-0_11

Yang, H. (2018). VR Technology and Its Application and Prospect in the Field of University Education Technology. *Proceedings of the 2018 International Symposium on Humanities and Social Sciences, Management and Education Engineering (HSSMEE 2018)*. https://doi.org/10.2991/hssmee-18.2018.53

Yildirim, C. (2024). Transformative Virtual Reality Games for Adaptive Sports Training: Exploring the Perceptions of Individuals with Mobility Impairments. *International Journal of Human-Computer Interaction*, 1–13. https://doi.org/10.1080/10447318.2024.2311970

Young, G., Stehle, S., Walsh, B., & Tiri, E. (2020). Exploring Virtual Reality in the Higher Education Classroom: Using VR to Build Knowledge and Understanding. *JUCS - Journal of Universal Computer Science*, 26(8), 904–928. https://doi.org/10.3897/jucs.2020.049

Zhang, Q. (2022). Development and Analysis of

Educational Virtual Reality System Using Static Image. *Mobile Information Systems*, *2022*, 1–9. https://doi.org/10.1155/2022/8592533

Zhang, Y., & Tsai, S.-B. (2021). Application of Adaptive Virtual Reality with AI-Enabled Techniques in Modern Sports Training. *Mobile Information Systems*, *2021*, 1–10. https://doi.org/10.1155/2021/6067678