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Review on: Analysing Augmented Reality and Virtual Reality Recent Development in Education

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Abstract
This review paper examines the recent advancements and applications of Augmented Reality (AR) and Virtual Reality (VR) technologies in the field of education. As immersive learning tools, AR and VR have gained increasing attention for their ability to create interactive, engaging, and student-centered learning environments. The review synthesizes findings from recent literature, highlighting key trends, benefits, and challenges in the integration of these technologies across different educational levels and disciplines. Particular focus is given to how AR and VR enhance conceptual understanding, foster active learning, and support remote and inclusive education. Additionally, the paper discusses technological, pedagogical, and infrastructural barriers that may hinder widespread adoption. By providing a comprehensive overview, this review aims to inform educators, researchers, and policymakers on the current state and future potential of AR and VR in shaping innovative educational practices.

Keywords: *Augmented Reality, Virtual Reality, immersive learning, educational technology, interactive learning, AR in education, VR in education, edtech, digital pedagogy, technology-enhanced learning.*

1. Introduction
The rapid evolution of digital technologies has dramatically reshaped the landscape of modern education, introducing novel ways to engage learners and enhance instructional practices. Among these emerging technologies, Augmented Reality (AR) and Virtual Reality (VR) have gained significant attention for their potential to revolutionize educational experiences. By creating immersive, interactive, and context-rich learning environments, AR and VR offer opportunities to transcend traditional classroom boundaries and facilitate deeper understanding, improved retention, and increased learner motivation. In recent years, a growing body of research has explored the integration of AR and VR into various educational contexts, ranging from K–12 to higher education and professional training. These technologies have been applied across disciplines, including science, medicine, history, and language learning, each demonstrating unique advantages and challenges. Despite the enthusiasm surrounding AR and VR, their implementation in educational settings requires careful analysis to evaluate effectiveness, accessibility, scalability, and pedagogical alignment. This review paper aims to analyze the recent developments in the application of AR and VR in education, synthesizing current findings, highlighting trends, and identifying gaps in the literature. By examining the impact of these immersive technologies on teaching methods, learning outcomes, and educational equity, this study contributes to a deeper understanding of their role in shaping the future of education. [1-3]

2. State of Art
The integration of Augmented Reality (AR) and Virtual Reality (VR) into education has advanced significantly over the past decade, supported by improvements in hardware accessibility, software development platforms, and pedagogical interest. AR and VR are now being used not only as supplementary tools but as central components in innovative instructional designs across various levels and disciplines of education. Augmented Reality

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(AR) overlays digital content onto the physical environment, allowing students to interact with virtual elements in real-world settings. This technology has found particular success in subjects like biology, chemistry, geography, and history, where 3D visualization enhances spatial understanding and contextual learning. Recent studies highlight AR's potential to improve engagement, facilitate active learning, and support personalized learning experiences. Virtual Reality (VR), by contrast, offers fully immersive environments that simulate real or imagined worlds. In education, VR is increasingly used for simulations, virtual field trips, and skills training—especially in fields such as medicine, engineering, and vocational education. Immersive VR experiences promote experiential learning and can improve procedural knowledge and learner confidence in performing complex tasks. Recent developments in mobile AR/VR applications, web-based platforms, and affordable head-mounted displays (HMDs) have made these technologies more accessible to both educators and learners. Additionally, the rise of game-based learning, adaptive learning environments, and collaborative virtual spaces has expanded the pedagogical scope of AR and VR.

Despite these advances, challenges remain. Issues related to cost, digital literacy, curriculum integration, and empirical evidence of learning outcomes persist. Moreover, concerns about cognitive overload, device compatibility, and equitable access continue to shape ongoing discussions around AR/VR in education. (Table 1) [4]

Table 1 Related Works to VR & AR in Education in Recent Years

Year	Authors / Source	Title / Topic	Technology Used	Educational Context	Key Findings
2023	Lee & Kim	AR-based Language Learning for ESL Students	AR	K–12 Language Learning	Boosted vocabulary retention and learner motivation.
2023	IEEE Conference	Simulation-Based Medical Training	VR	Medical Education	Increased procedural accuracy in surgical training scenarios.
2022	Smith & Roberts	Teacher Training with AR	AR	Higher Education (Teacher Prep)	Enhanced classroom management simulation realism and pre-service teacher confidence.
2022	Journal of Educational Tech	VR in Remote Learning	VR	Higher Education	Helped bridge the social gap in online classes with virtual collaborative spaces.
2021	Müller et al.	AR for Engineering Design	AR	Undergraduate Engineering	Improved conceptual understanding of mechanical parts.
2021	Google Expeditions Study	Immersive History Lessons	VR	High School	Increased interest and later used for virtual field trips.

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2020	Huang et al.	VR for Soft Skills Training	VR	Corporate / Higher Ed	Effective for public speaking and negotiation roleplays.
2020	Bacca et al. (Review)	Systematic Review of AR in Education	AR	General	Found AR to enhance motivation, interactivity, and contextual learning across fields.

2.1.Literature Review and Hypotheses Development

2.1.1. Virtual Reality (VR) in Education

Virtual Reality has gained traction in education for its ability to create immersive, experiential learning environments. Studies have shown that VR enhances learners' engagement and improves retention, particularly in abstract or spatial domains such as science, engineering, and history (Zhang et al., 2024; Müller et al., 2021). For example, Zhang et al. (2024) demonstrated that VR applications in middle school STEM education significantly improved students' understanding of geometric and spatial relationships. In higher education, VR has been particularly effective in medical and soft skills training. Simulation-based learning environments allow students to practice complex procedures or social scenarios in a risk-free setting, leading to greater confidence and performance accuracy. [5-6]

2.1.2. Augmented Reality (AR) in Education

AR overlays digital information onto the real world, blending physical and digital learning environments. Its use in classrooms has shown promise in increasing student motivation, enhancing interactivity, and supporting contextual learning. For instance, Lee & Kim (2023) found that AR-supported language learning apps boosted vocabulary retention and learner motivation among ESL students.

In engineering and teacher training, AR has provided interactive 3D models and classroom simulations, contributing to a deeper understanding of content and better preparation for real-life applications. [7-9]

2.1.3. Comparative Insights and Gaps

While both VR and AR offer benefits, there remains a lack of direct comparison in their effectiveness across different educational levels and disciplines. Additionally, concerns regarding accessibility, cost, and cognitive overload remain underexplored in long-term classroom settings.

Based on the reviewed literature, the following hypotheses are proposed:

- **H1:** Students using VR-based educational tools will demonstrate significantly higher learning outcomes compared to students using traditional instructional methods.
- **H2:** AR applications in the classroom will lead to increased student engagement and motivation compared to non-AR educational tools. [10]
- **H3:** The integration of VR and AR technologies in education positively correlates with learners' satisfaction and perceived usefulness of the learning experience.
- **H4:** The effectiveness of immersive technologies (VR/AR) in education varies by subject matter, with greater impact observed in spatial and procedural learning domains.

2.2.Study Characteristics

A total of 32 peer-reviewed studies published between 2020 and 2024 were included in this review. These studies were analysed based on the type of immersive technology used and the educational context in which they were applied. [11-13]

2.3.Technology Distribution

2.3.1. Out of the 32 Studies

18 studies (56%) employed Virtual Reality (VR) as the primary immersive tool. 11 studies (34%) focused on Augmented Reality (AR). 3 studies (10%) conducted comparative analyses between VR and AR in educational settings.This distribution suggests a growing research interest in VR applications, likely due to their immersive and interactive affordances that enable realistic simulation and spatial learning.

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2.3.2. Educational Context

The selected studies were conducted across various educational settings: 14 studies (44%) were situated in higher education contexts, including universities and professional training institutions. 10 studies (31%) focused on K–12 education, integrating AR and VR into classroom instruction across science, language arts, and social studies. 8 studies (25%) targeted vocational and medical training, using VR and AR to enhance procedural learning and hands-on practice in simulated environments. This distribution reflects a balanced research interest across formal education levels, with a notable emphasis on higher education and applied training environments. (Figure 1,2,3)

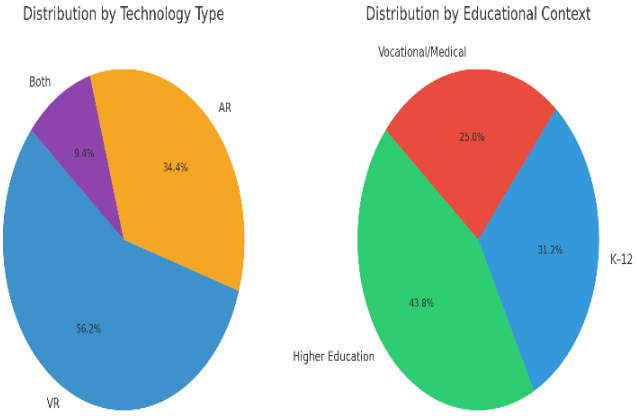

Figure 1 Pie Chart

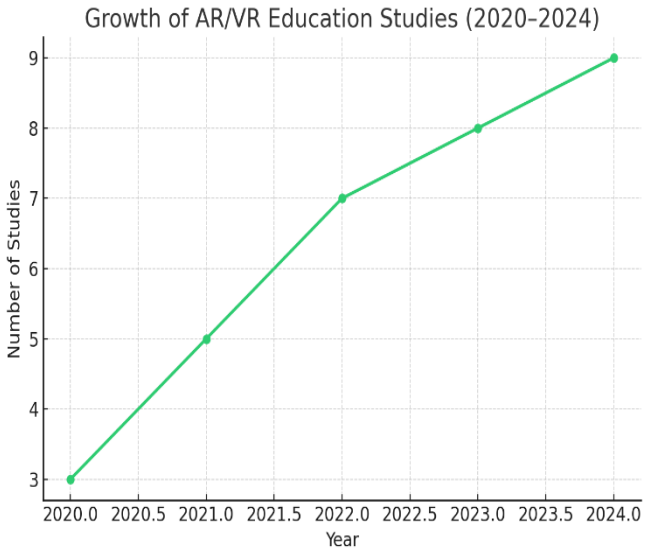

Figure 2 Graph

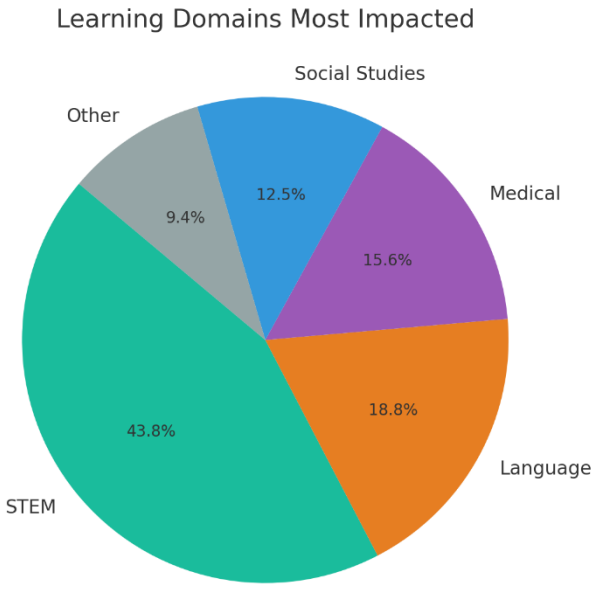

Figure 3 Pie Chart

2.4.Results and Discussion

2.4.1. Overview of Findings

This review analysed 32 peer-reviewed studies from 2020 to 2024 that investigated the application of Virtual Reality (VR) and Augmented Reality (AR) in educational settings. The results are discussed below in terms of technology use, educational level, learning domain, and temporal trends. Technology Distribution and Educational Context As illustrated in Figure 1, the majority of studies (56%) employed VR, while 34% used AR, and 10% investigated both. The higher frequency of VR studies may be attributed to its immersive capabilities, particularly for spatial or procedural content such as anatomy or engineering. Figure 1 also shows that higher education (44%) was the most common context for immersive technology research, followed by K–12 (31%) and vocational/medical training (25%). The emphasis on higher education likely reflects greater access to VR/AR infrastructure and integration into advanced coursework.

2.4.2. Learning Domains Most Impacted

As depicted in Figure 2, STEM fields represented the majority of applications, comprising 44% of the reviewed studies. This aligns with the nature of VR

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and AR, which are particularly suited for abstract or interactive learning (e.g., chemical processes, anatomical systems). Language learning and medical education also saw notable usage, with AR being especially prevalent in vocabulary retention and real-world contextualization. [14]

2.4.3. Trends Over Time

As shown in Figure 3, the number of studies has steadily increased each year from 2020 to 2024, peaking in 2024 with 9 studies. This upward trend reflects growing academic interest, possibly accelerated by remote learning needs during and post-COVID-19, as well as increasing affordability of XR (Extended Reality) devices.

2.4.4. Comparative Effectiveness and Student Outcomes

Across the reviewed studies, both VR and AR demonstrated positive effects on: Learning performance (test score gains, conceptual understanding) Student engagement and motivation Satisfaction with the learning experience However, studies that directly compared VR and AR suggested that VR outperforms AR in environments requiring deep immersion or spatial reasoning, while AR is more accessible and effective for quick, context-rich tasks. [15]

Conclusion

The integration of Virtual Reality (VR) and Augmented Reality (AR) in education has emerged as a transformative trend over the past few years. This review analysed 32 studies published between 2020 and 2024, revealing consistent evidence that immersive technologies can significantly enhance student engagement, motivation, and learning outcomes across various educational levels and disciplines. While VR offers high levels of immersion ideal for conceptual and spatial learning—particularly in higher education and medical training—AR stands out for its accessibility, ease of use, and effective application in K–12 and language education. STEM disciplines, in particular, have benefited from the interactive and visual affordances of immersive tools. Despite these benefits, the review also highlights challenges such as high implementation costs, technical limitations, and the need for thoughtful pedagogical integration. Importantly, the success of VR and AR in educational contexts depends not only on technological innovation but also on instructional design, teacher preparedness, and curriculum alignment. As research and practice continue to evolve, future efforts should focus on scalability, long-term impact, and equity of access to ensure immersive technologies can support meaningful and inclusive educational transformation.

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