Enhancing Learning Experiences: The role of mixed reality in Higher Education

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***Abstract**. Immersive technologies, such as Augmented Reality, Virtual Reality, and Mixed Reality, are increasingly adopted in higher education for their ability to enhance learning through interactive, experiential environments. This systematic literature review, following PRISMA guidelines and covering 45 papers from 2020 to 2024, examines the impact of mixed reality on student engagement, personalized and collaborative learning, and its limitations. Findings indicate that these technologies enhance learning outcomes and satisfaction; however, they face barriers such as high costs, infrastructure demands, and cybersickness. The review provides recommendations to address these challenges and identifies future research needs, particularly in under-resourced educational settings.*

Keywords. Augmented reality; extended reality; higher education; immersive learning; mixed reality; student engagement; virtual reality.

1 Introduction

The rapid advancements in technology have brought about changes in various aspects of our lives, including the way we live, communicate with each other, work, and learn. As these innovative technologies evolve, the world remains connected through network nodes, increasing accessibility to these advanced technologies. This kind of accessibility provides a platform for different people to utilise these technologies. Current technologies changing how we learn are immersive technologies. These technologies have the characteristic to enhance the way we live and how we learn (Harjana et al., 2023). Immersive technologies encompass augmented reality (AR), virtual reality (VR), mixed reality (MR), and the umbrella term extended reality (XR). These kinds of technologies have the functionality of blending the physical and virtual worlds.

The capabilities of immersive technologies differ; each technology has unique strengths that make it a suitable choice for specific applications, depending on the case study. With each unique strength, the common goal remains to blend the physical and virtual worlds to create an interactive environment.

Mixed Reality (MR) integrates components from Augmented Reality (AR) and Virtual Reality (VR), resulting in a hybrid reality where physical and digital objects coexist. Extended reality (XR) is an immersive technology that involves blending virtual and real-world elements to create a virtual environment where digital and physical objects interact (McMillan et al., 2017). Mixed reality is also defined as one of the emerging technologies that aids in facilitating teaching and learning processes (Suryodiningrat et al., 2021). This technology enables students to interact with 3D models and simulations, promoting a deeper understanding of disciplines ranging from science and technology to the arts (Baltezarevic & Baltezarevic, 2024).

The use of this technology in education has demonstrated an improvement in the quality of teaching and learning experiences (Harjana et al., 2023). This immersive technology creates realistic scenarios that enhance students' cognitive abilities (Petruse et al., 2024). Despite the potential benefits of adopting this technology in higher education, several limitations exist, including health concerns, student engagement issues (Steyn et al., 2024), and accessibility barriers.

This paper explores the role of Mixed reality technologies in higher education. It contributes to understanding the potential of how these technologies can enhance learning experiences and improve educational curricula despite various challenges. The objective is to provide educators in higher education with insights and recommendations on the adoption of extended reality for academic advancement. The guiding research question is: What role can immersive technologies play in Higher Education? The outline of this paper begins with an introduction that establishes the research problem and objectives. This is followed by a literature review on extended reality, which includes virtual reality, augmented reality, and mixed reality, as well as the adoption of this technology in higher education and its limitations. The research method, selection criteria, findings, discussion, and conclusion are presented, followed by a recommendation for future research.

2 Literature review

The use of Mixed Reality (MR) technology in higher education has sparked considerable interest, particularly because it promises to enhance learning experiences across various disciplines. Chen et al. (2017) revealed that MR has significant promise in medical education, particularly in training and surgical planning. The authors contend that MR can give essential patient-specific data, thereby improving the training landscape for medical practitioners. However, they also acknowledge the technological constraints and expenses that have hampered wider acceptance, paving the way for future breakthroughs in this field.

Birt and Cowling (2018) analysed the use of MR in design education using a comparison visualisation methodology. Their findings suggest that MR technologies enhance student outcomes by fostering reflective learning and participatory teaching methods. They argue for a departure from traditional approaches, emphasizing the need for further study to determine which technologies best serve the diverse learning modes in higher education, a point echoed by various authors (Steyn et al., 2024a; Steyn et al., 2024b). MR applications need to be tailored to maximize educational benefits (Chen et al., 2017).

He & Perlin (2020) studied the usefulness of MR in classrooms utilizing the Chalktalk software platform. The study examined how MR can enhance engagement and retention during face-to-face encounters, providing empirical data to support its inclusion in educational methods. This study supports the idea that MR can enhance traditional learning settings by making them more engaging and effective.

Misirlis et al. (2023) explored students' plans to use Meta-Education technology, including MR applications. They highlight both the potential benefits, such as improved learning settings and gamification, and the obstacles posed by technical adoption, infrastructure, and cultural differences. Their findings indicate that while MR has enormous promise in education, there are still considerable barriers to adoption.

2.1 Evolution of technology in education

MR technologies have advanced significantly in recent years, with improvements in both hardware and software enabling educational institutions to utilize them as effective teaching aids. Augmented reality and virtual reality technologies have gained popularity in higher education due to their ability to engage students through experiential learning and immersive simulations. These technologies are commonly used in STEM fields, where visualization and interaction with complex systems are critical (Banjar et al., 2023; Hughes et al., 2005).

Augmented Reality (AR) overlays digital content in the real world, allowing students to perceive and interact with 3D objects while remaining in their physical context. This method is beneficial in subjects such as biology and engineering, where augmented reality can provide visual representations of molecular structures, anatomical models, and mechanical systems (Valladares Ríos et al., 2023). Virtual Reality (VR) immerses students in totally virtual surroundings, allowing them to explore and engage with information in ways that are not feasible in the real world. In medical education, virtual reality (VR) will enable students to practice surgical procedures, explore human anatomy, and mimic clinical settings. This allows students to apply their practical learning skills without the hazards associated with real-life practice. Virtual reality is also making substantial contributions to the humanities, providing immersive experiences in archaeology and history (Valladares Ríos et al., 2023).

2.2 The adoption of mixed reality in higher education

MR technologies are utilized in various higher education disciplines, including STEM fields such as science, engineering, and medicine. These technologies offer interactive simulations that help students grasp complex systems, thereby enhancing information retention and practical application (Marks & Thomas, 2022; Alexander et al., 2019).

Virtual reality simulations in medical education enable students to practice operations and learn anatomy without the use of cadavers or real-life patients, hence increasing confidence and technical abilities. Augmented reality augments lectures and demonstrations by presenting 3D renderings of body parts, allowing students to learn anatomy interactively (Baniasadi et al., 2020).

In the arts and social sciences, a mixed reality environment enables students to visit historical locations or engage in digital cultural activities virtually. According to studies, students who studied ancient civilizations using virtual reality had a greater awareness and knowledge of historical events and societal systems than those who used textbooks alone (Banjar et al., 2023).

Mixed reality offers numerous significant advantages in educational contexts, including increased engagement and motivation, enhanced comprehension of complex topics, and support for collaborative learning. The immersive aspect of mixed-reality settings draws students in and encourages them to engage actively in their studies. For example, in physics classes, students who used virtual reality simulations retained 25% more complicated concepts than those who learned through lectures and textbooks. MR-enhanced collaborative learning has been demonstrated to improve students' collaboration and problem-solving skills (Munfaridah et al., 2021).

2.3 Challenges of adopting MR

Mixed Reality (MR) has the potential to improve or even revolutionize learning experiences in higher education. However, despite its numerous benefits, the broad adoption of mixed reality is hindered by several external challenges, including high prices, infrastructure limitations, and the readiness of educators and students to utilize the technology (Banjar et al., 2023).

The high cost of hardware and software, especially in underdeveloped countries, can significantly contribute to the integration of these immersive technologies in higher education. Underdeveloped countries have several socio-economic issues which result in an unequal standard of living. This factor limits equal student accessibility to the use of mixed reality, which hinders inclusive growth in education (Kezia Herman & Bordoloi, 2024). Technical impediments, such as a lack of reliable and fast internet connections, equipment that does not cater to all students, and a lack of user-friendly interfaces, hinder the effectiveness of mixed reality in lecture rooms, which frustrates both educators and students. Educators must possess specific technical skills and know how to incorporate MR into their teaching methods effectively. Training must be available to upskill educators (Harjana et al., 2023) (Blooma et al., 2022) to ensure that they are equipped to deliver quality educational content.

According to Harjana et al. (2023), the key challenges to the adoption of mixed reality include a lack of funding, a lack of understanding among users on how to operate immersive technologies, and a slow adaptation among students and teachers. These challenges raise significant concerns. The study found that more than 90% of students consider learning with mixed reality to be more effective than traditional methods. Despite these challenges, the potential benefits of mixed reality in higher education are too significant to ignore. Mixed reality can transform the way students learn and foster collaboration between students and their educators in ways that traditional methods cannot. Mixed reality can provide content for different education sectors. It is necessary to address these issues so that higher education can fully reap the benefits of the power of mixed reality (Birt et al., 2018) to create engaging and effective learning environments.

3 Methodology

This study uses a systematic literature review to synthesize current knowledge, identify research gaps, and offer recommendations (Dinter et al., 2021). Following established guidelines (Braun & Clarke, 2006), relevant literature was sourced from major databases via the University of Pretoria's library, which includes ProQuest, Science Direct, ACM Digital Library, IEEE, and Emerald Insight.

The following search string was used on the identified databases: ("Mixed Reality") AND ("Higher Education") OR (tertiary education) AND ("Virtual Reality") AND ("Extended Reality") AND ("Augmented Reality").

The review included only peer-reviewed, open-access research articles and conference papers published in English between 2020 and 2024, filtered by the relevant keywords. Non-peer-reviewed research papers were excluded. This is to avoid grey literature and maintain accuracy and reliability.

Using the PRISMA flowchart, 239 records were identified, duplicates and irrelevant studies were removed, and 42 papers meeting all criteria were included in the final review (Fig. 1).

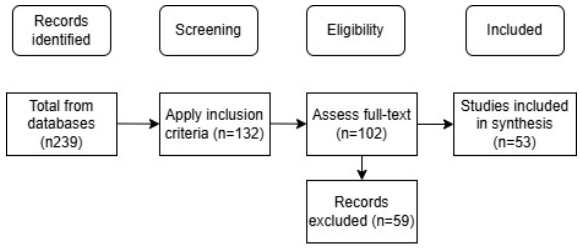

Figure 1. PRISMA flowchart

Data extraction, guided by the PRISMA flowchart, selected articles aligned with the study's objectives and criteria. Thematic analysis was used to systematically identify codes and themes (Braun & Clarke, 2006; Clarke et al., 2015). With support from generative AI (ChatGPT, 2024), key themes emerged: 'Enhancing Learning Experiences' (with subthemes 'Interactive Learning' and 'Personalized Learning') and 'External Challenges' (including 'Financial Constraints' and 'XR Limitations'). Retrieved articles were grouped accordingly.

4 Findings

The discussion of the adoption of mixed reality or similar technologies in higher education has become quite popular in recent years.

Table 1. Themes identified

Main Theme	Sub theme	References
Enhancing Learning Experiences	Interactive learning	(Andalib & Muntazar, 2024), (Banjar & Campbell, 2022), (Banjar et al., 2023), (Bermejo et al., 2023), (Dong et al., 2023), (Dutt et al., 2022), (Harjana et al., 2023), (Hensen & Klamma, 2022), (Hutson & Olsen, 2022), (Izard et al., 2021), (Jiawei & Mokmin, 2023), (Jin et al., 2022), (Li, 2023), (Lohfink et al., 2022), (Meccawy, 2023), (Pan et al., 2021), (Pellas et al., 2021), (Perçuku & Minkovska, 2022), (Salloum et al., 2023), (Sofiadin, 2023), (Wang & Li, 2024)
	Personalised learning	(Alkhudair et al., 2024), (Jiang et al., 2024) ,(Moser et al., 2024), (Peters et al., 2021), (Petruse et al., 2024), (Suryodiningrat et al., 2021), (Tang et al., 2020), (Staddon, 2020)
	Financial constraints	(Antón-Sancho et al., 2023), (Ewais et al., 2022), (Ironsi, 2023), (Laine & Lee, 2024), (Marks & Thomas, 2022), (Nesenbergs et al., 2021)
External Challenges	XR limitations	(Baxter & Hainey, 2020), (Beetul et al., 2023), (Duan, 2024), (Kezia Herman & Bordoloi, 2024),(Lai & Cheong, 2022), (Li et al., 2021), (Obeidallah et al., 2023), (Radianti et al., 2020), (Hajirasouli & Banihashemi, 2022)

Regarding geographic location and types of papers, Fig. 2 and Table 2 provide a visual representation of the number of articles published on the topic of mixed reality adoption in higher education from 2020 to mid-2024. The trend in these figures suggests that more papers are being published to address the topic, indicating a growing interest in the adoption of mixed reality technologies in higher education.

Table 2. Papers per conference or Journal

Year	Conference papers	Journal papers
2020	0	4
2021	3	4
2022	5	5
2023	9	4
2024	8	1

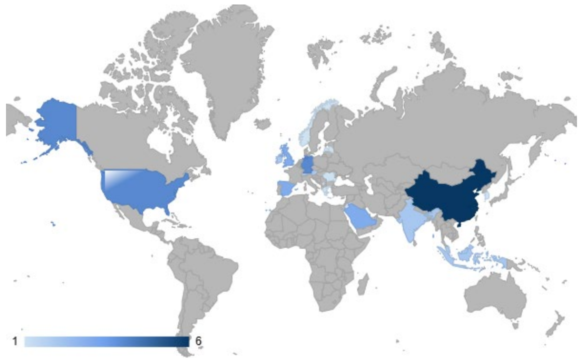

Figure 2. Geographical location

The papers were published in different countries. The country with the most published papers is China with the least being the countries in the light-shaded blue. No papers were identified in the countries shaded in the grey colour.

The papers discovered address the use of extended reality technologies can be used in different educational fields.

Fig. 3 indicates that extended reality technologies are commonly used STEM fields in education.

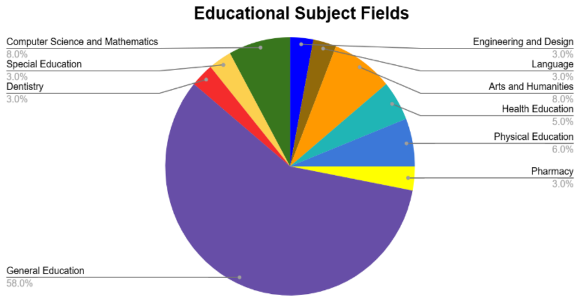

Figure 3. Various fields in education using XR

5 Discussion

5.1 Enhancing learning experiences

Mixed reality technologies promote interactive and personalized learning experiences. Students can utilize these immersive technologies to enhance their understanding of subject matter in technical fields such as engineering, architecture, medicine, geography, and science (Andalib & Muntazar, 2024). The virtual simulations enable students to interact with complex 3D model prototypes, providing them with a real-life experience that is not available with traditional methods (Andalib & Muntazar, 2024). Interactive learning through virtual simulations supports embodied learning theory, which allows students to learn by applying cognition and physical interaction with objects (Jin et al., 2022).

These simulations improve students' geometric analysis and creativity skills (Harjana et al., 2023). Immersive technologies are primarily applied in subjects across both STEM and the Bachelor of Arts fields. They are commonly used in science and technology studies (Dong et al., 2023; Banjar et al., 2023; Meccawy, 2023) due to the immersive qualities of these fields. Art is still predominantly presented using traditional teaching methods in classrooms (Jiawei & Mokmin, 2023); however, art content is also offered using virtual reality (VR). Extended is used to arrange a virtual tour of art museums for Bachelor of Arts students (Hutson & Olsen, 2022) and archaeological museums for Humanities students (Lohfink et al., 2022). A virtual tour allows users to view, engage with, and interact with the artwork, thereby witnessing an authentic virtual experience through a learning process (Lohfink et al., 2022).

In health and medical studies, extended reality tools are enabling health students to interact with holograms rather than physical bodies (Bermejo et al., 2023); a similar concept can be applied in ICT coursework. Villena-Taranilla et al. (2022), cited in Dong et al. (2023), reported that immersive technologies are used in the Bachelor of Arts field by displaying historical tales and historical artefacts to students (Dong et al., 2023). Extended reality is applied in sports training. Putranto et al. (2023) outlined how VR in sports training can enhance players' performance analysis, prevent injuries, and improve training skills through various training scenarios. This demonstrates that extended reality technologies are leveraged to enhance the interactive learning experience of students across multiple fields of education.

Undergraduate computer science students were enrolled in a practical course to apply their skills using MR concepts on software methodologies and development lifecycles (Hensen & Klamma, 2022). The students were divided into groups to collaborate on the project requirements.

Tang et al. (2020) investigated the learning effectiveness of students who enrolled in the design subject. One group of students studied using HoloLens, a mixed-reality headset that enables digital content to overlay with the real-life environment. Students used HoloLens technology to visualize the digital model of an aircraft turbofan. This demonstrates how students can benefit from personalized learning using mixed reality features; this content delivery enhanced how information is provided through the visualisation of the digital model. Students were able to interact with the digital model in real time through hand gestures, voice commands, and gaze (Tang et al., 2020), thereby enhancing their learning. An alternative to the use of headsets is Light Field Display (LFD), a technology that projects 3D images through light in multiple directions. Students can view the pictures without wearing headsets (Pan et al., 2021), achieving interactive learning through simulation. Active participation enhances students' understanding of the subject content (Harjana et al., 2023).

The use of extended reality technologies provides a platform for students to engage in class interactively (Banjar et al., 2023) using 2D and 3D environments. Mixed reality enables real-time collaboration, allowing multiple users to interact within the same virtual space and exchange feedback with one another (Wang & Li, 2024). This dynamic interaction promotes deeper learning and more effective collaboration (Perçuku & Minkovska, 2022). The Metaverse is a virtual world that enables connections between the virtual and offline worlds (Salloum et al., 2023). Higher educational institutions can be part of the Metaverse, allowing their stakeholders to connect. Traditionally, lectures are delivered by one lecturer to a small audience, which compels all parties to stay in place in the lecture room. The Metaverse offers users a "cyber-physical" experience, enabling them to navigate seamlessly between physical and online environments (Salloum et al., 2023). This kind of environment makes learning more engaging, interactive, and interesting for students in higher education.

Students exposed to virtual reality-enhanced learning experiences display higher levels of engagement and enhance their critical thinking and problem-solving skills (Pellas et al., 2021).

The HoloLens and Oculus mixed-reality technology is used to deliver human gross anatomy laboratory content to medical students (Jiang et al., 2024; Izard et al., 2021). Through visual simulations, students were able to perform surgical operations while simultaneously receiving feedback on the surgical steps to take and patient information (Jiang et al., 2024). Students were able to learn without the risks associated with surgery. The active use of such immersive technology enables users to enhance their skills, thereby reducing the likelihood of human error (Jiang et al., 2024) and increasing the rate of successful operations.

Extended reality environments cater to the diverse learning styles of users. This is achieved through the active development of the training content in an extended reality Learning Content Management System (LCMS) based on an individual's user data (Moser et al., 2024). The integration of generative AI with the extended reality environment can enhance the generation of content, thereby improving the adaptive learning experiences of users (Moser et al., 2024).

Expanding on the benefits of extended reality allows students to personalize their learning experiences. Students have their preferred learning methods, and an extended reality, such as MR, is flexible enough to accommodate each student's learning methods (Suryodiningrat et al., 2021). This allows students to interact in the classroom in their way. A mixed reality system enhances student interaction, which improves students' confidence in learning and their self-efficacy as they learn at their own pace.

Studies suggest that age may have an influence on students' learning outcomes using technology-enhanced learning (Staddon, 2020). Older students outperformed younger students when using a technology-enhanced learning system (Staddon, 2020), indicating that age is a factor to be considered when designing and implementing technology-enhanced learning systems (Petruse et al., 2024) to accommodate different age groups in higher education.

A user-centred design (UCD) approach ensures that users' needs are accounted for from the beginning of the design process (Petruse et al., 2024) until the end of the design lifecycle. User-centred design ensures that augmented reality environments are designed to meet users' needs, enhance the end-user experience when using the environment, and accommodate their preferences (Petruse et al., 2024). These components ensure meaningful learning experiences when using augmented reality environments. To understand a user's needs, a persona needs to be developed (Petruse et al., 2024) to inform the design of interfaces in an augmented reality environment. Failure to include users' needs may result in students being confused about how to use the environment, which defeats the goal of enhancing students' learning experiences (Petruse et al., 2024).

The adoption of extended reality has several benefits, including enhanced student engagement, interactive learning, collaborative learning, and personalized learning; however, how do educators measure the effectiveness of extended reality technologies in their lecture rooms? Sofiadin (2023) provided students with a quiz to evaluate their understanding of learning activities using an XR application.

The results show a significate difference in the students' performance. 58 students used the XR app learning experience, 95% of the students scored a grade A (81–100), and the remaining 5% scored a grade B (71–80). As opposed to the 63 students who did not use the XR app learning experience, only 14% scored a grade A, 67% scored a grade B and 19% scored a grade C (41-60).

The results show that more students who used the XR application obtained a mark between 81-100 than the students who did not utilise the XR application. The difference in the number of students is quite significant, validating that immersive technologies have the potential to improve students' achievements.

Learning difficulty is an umbrella term for learning disorders that affect one's capability to learn (Dutt et al., 2022); examples include Dyslexia, Dyspraxia, and Perceptual Disabilities. Students who live with a learning difficulty get below-average marks compared to students of their age who do not live with any learning difficulty (Dutt et al., 2022). Learning disabilities can put a strain on how students grasp information, leading to demotivation and reduced academic performance. Extended reality technologies can provide support for individuals in need (Dutt et al., 2022), including those who are visually or hearing-impaired. Students can use interactive learning environments to enhance their learning outcomes.

Extended Reality (XR) technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), have demonstrated significant potential benefits in enhancing learning experiences through interactive and personalized education. These benefits include increased student engagement and motivation. These immersive technologies allow students to interact with 3D models using embodied learning. This learning helps students understand educational content in depth. Students can apply the skills they learned in the virtual world in real-world scenarios. Extended reality technologies have the flexibility to cater to diverse learning styles, allowing students to learn at their own pace while applying personalized learning. While existing literature has outlined the benefits and challenges of immersive technologies, there is limited guidance on how institutions can integrate these technologies pedagogically. To address this gap, this paper proposes a conceptual model designed to guide the implementation of immersive technologies in higher education. The details of the model are later discussed in the paper.

5.2 External challenges

The following section reflects the findings discussed under the theme of external challenges, focusing on the sub-themes of financial constraints and XR limitations. Mixed reality technologies require specialized hardware, including virtual reality head-mounted displays, high-performance computers, interactive devices, and virtual reality software. The cost of a virtual reality headset can range from $100 to $1,000 (Marks & Thomas, 2022), depending on the quality and quantity required for purchase. Virtual reality head-mounted displays require a connection to high-performance computers that can handle the intensive processing of virtual reality environments. In particular, organising a functional virtual reality lab equipped with 26 units of quality hardware at the University of Sydney costs over AU$100,000 (Marks & Thomas, 2022). While these figures provide a proper estimate, the cost of virtual reality hardware has been subject to fluctuation since 2022, due to technological advancements and inflation.

Additionally, facility and operational costs are incurred, which include classroom space and the Internet. Classrooms must be designed to allow free movement during virtual interactions with the virtual reality head-mounted displays. Small classrooms cause a lack of oxygen flow, which results in a hot and stuffy environment (Marks & Thomas, 2022); thus, redesigning classrooms adds to the financial burden. Slow internet connectivity can hinder the sharing of virtual reality content; good infrastructure is required to support high internet connectivity for streaming or to download content for all users (Marks & Thomas, 2022). A critical challenge to the adoption of immersive technologies in higher education is the readiness of infrastructure in higher educational institutions (Ewais et al., 2022). The lack of Internet, inadequate IT infrastructure, and the cost of hardware and licensing maintenance create a limitation (Antón-Sancho et al., 2023).

The use of immersive technologies in Tanzania is quite minimal (Kezia Herman & Bordoloi, 2024), with some activities of augmented reality in the tourism space; however, there are few opportunities for the engagement of augmented reality in higher education. Other African countries could experience the same challenge, which is why no articles were found published in any African countries relating to the research question. The lack of good infrastructure is a barrier that makes it challenging to ensure that extended reality technologies are accessible (Kezia Herman & Bordoloi, 2024).

The costs of adopting immersive technologies could increase educational inequalities (Ironsi, 2023), which, unfortunately, stunts the growth of digital inclusion, as not all students may have the financial means to have access to such equipment.

The skill gap between trained educators who are proficient in using immersive technologies is also a challenge experienced when incorporating extended reality (Kezia Herman & Bordoloi, 2024). This challenge is a result of the limited adoption of immersive technologies, specifically augmented reality, in higher educational institutions in India (Hajirasouli & Banihashemi, 2022). In India, 80.6% of faculty and students have never attended any training on augmented reality technologies (Kezia Herman & Bordoloi, 2024). Inadequate augmented reality and virtual reality training programs can lead to poor collaborative learning experiences for both educators and students, as educators may struggle to deliver content efficiently, and students may struggle to grasp the concepts being taught. Higher education institutions should organise extended reality-based training materials that educators can enrol in (Duan, 2024) to learn how to navigate the basic operating skills necessary for preparing their classes. Additionally, they should invite experts to the sessions to provide their advice on real scenarios (Duan, 2024). Additionally, to combat this challenge, students must familiarise themselves with the use of immersive technologies at their own pace (Nesenbergs et al., 2021) by also integrating traditional learning methods.

Prolonged use of mixed reality equipment can cause users to experience cybersickness (Laine & Lee, 2024). Cybersickness is a visually induced form of motion sickness that causes symptoms such as discomfort, dizziness, headache, and dry eyes, among others (Laine & Lee, 2024). Individuals who have epilepsy, frequent headaches, and vertigo are more susceptible to cybersickness (Beetul et al., 2023), symptoms caused by prolonged use for more than an hour. Fortunately, users do not experience cybersickness to the same degree (Beetul et al., 2023). The recommended practice to minimise the symptoms of cybersickness is not to use immersive technology devices for more than two hours (Beetul et al., 2023).

Baxter and Hainey (2020) asked 83 participants for their opinions on the challenges associated with adopting virtual reality technology. One participant mentioned that they were unable to use the head-mounted displays because they wear glasses (Baxter & Hainey, 2020). The equipment's inability to accommodate users who wear glasses is a limitation. This raises a concern about other physical limitations users may have that could restrict their ability to wear and use extended reality head-mounted displays. The current designs of immersive technological products are used more for entertainment-oriented than education-oriented purposes (Obeidallah et al., 2023; Radianti et al., 2020). These devices should have the functionality to allow users to edit the presented content (Radianti et al., 2020). The simulation functionality of immersive technologies does not necessarily appeal to all students. A study reported that some students expressed that the simulation does not replicate the sports training experiences of the real world (Li et al., 2021). This may hinder students from applying the skills learned in the virtual world to real-life experiences.

Extended reality offers numerous benefits; however, educators must ensure that they incorporate extended reality into their teaching methods to address known problems (Lai & Cheong, 2022). Ineffective implementations occur when there is a misalignment between the teaching objectives and the technological solutions provided. Mikropoulos and Natsis (2011), as cited by Lai and Cheong (2022), revealed that the use of virtual reality in education between 1999 and 2009 lacked a clear direction on how technology is used to solve pedagogical challenges (Lai & Cheong, 2022). It is essential to develop a curriculum that continues to deliver high-quality educational content, incorporating extended reality (Obeidallah et al., 2023).

While extended reality technologies offer exciting enhancements in education, several challenges must be addressed. Challenges include cost, infrastructure, educator training, accessibility, and health considerations. Higher educational institutions should focus on ways to overcome these barriers to have a seamless adoption of MR reality in academic curricula.

The adoption of Mixed Reality (MR) technologies in higher education holds great potential for enhancing learning by merging physical and virtual environments. This conceptual model, Fig. 4, outlines an approach to adopting mixed reality or other immersive technologies in higher education, highlighting key areas of focus which will be discussed further.

Figure 4: Conceptual model

Curriculum Development and Alignment

Higher education should integrate immersive technologies into the curriculum to maintain subject relevance. An educational advisory board, guided by experts, can modify and align the curriculum accordingly. Once adopted, the board should continuously optimize this approach to keep content relevant.

Infrastructure and Accessibility

To overcome financial barriers, institutions should seek funding and partner with governments and tech providers to lower costs. Equipment must be inclusive for all students, and classrooms redesigned for flexible, interactive learning.

Educator and Student Training

Successful adoption requires training educators to use mixed reality tools and adapt teaching methods effectively. Students also need training to engage with virtual content and personalize their learning.

Addressing Health, Safety, and Inclusivity

Higher education institutions should set safety guidelines for immersive technology use, including usage limits, breaks, and cybersickness management. Content should follow universal design principles and include accessibility features like voice commands and touch interfaces to support all students.

Strategic Partnerships and Collaboration

Higher education institutions should partner with industry leaders for internships and workshops, keeping mixed reality tools relevant and providing practical experience. Regional collaboration can also foster knowledge exchange and resource sharing, enriching the educational ecosystem.

6 Conclusion

This systematic review highlights the potential of mixed, virtual, and augmented reality to enhance learning in higher education through interactive simulations and 3D visualization. These technologies improve engagement, critical thinking, collaboration, motivation, and personalized learning, serving as valuable complements to traditional methods.

However, the review also reveals an apparent inequality in the global adoption of extended reality in higher education. Most of the reviewed studies originate from countries with developed economies, where institutions benefit from their country's advanced infrastructure, reliable connectivity, and financial resources. In comparison, regions in Africa remain underrepresented, both in research output and in adoption of extended reality, mainly due to financial constraints and a lack of infrastructural development.

Future research should address the adoption of extended reality in African higher education, where literature is scarce, to develop frameworks suited to the continent's socio-economic context, to ensure equitable access to innovative learning opportunities globally.

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