Simulation or Fake:
Will Extended Reality Provide a More Vivid Learning Experience?

Xiangyu Dong, University of Wales Trinity Saint David, United Kingdom

The European Conference on Education 2023
Official Conference Proceedings

Abstract
Extended Reality (XR), encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), is a unifying term for technologies ranging from fully real to entirely virtual environments. It's known for its potential to offer immersive and realistic learning experiences. EDUCAUSE Horizon Report: Teaching and Learning Edition, published by the US professional organization, mentioned extended reality three times as one of six technologies and practices that will influence the future development of higher education from 2020 to 2023. However, the quality of current systems for the application of XR in education varies; the effectiveness of the application is still somewhat controversial and needs in-depth discussion due to the limitations of the application equipment and other reasons. This research aims to explore the effectiveness of extended reality in education, in particular, whether extended reality can provide a more realistic and immersive learning experience. This study adopts a combination of literature review and case study analysis. Through a comprehensive survey of relevant literature, it analyses the definition, characteristics and application scenarios of extended reality technology and combines actual cases of XR in training to explore the effects and applications of XR in education. The study indicates that extended reality can provide a more realistic and immersive learning experience, especially when the system is highly interactive or with a virtual learning environment, which can enhance the sense of realistic and experiential learning.

Keywords: Extended Reality (XR), Immersive Learning Experience, Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR)

Introduction

Background

With the rapid advancement of digital technology, Extended Reality (XR), encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), has gradually become a cutting-edge trend and research focus in the field of education (Milgram et al., 1995). These innovative technologies, by constructing immersive and interactive virtual environments, have ignited endless possibilities for improving educational practices, thus attracting widespread attention and active investment from educational institutions and experts around the world (Johnson et al., 2016). However, despite the widely recognized potential and opportunities of XR in education, there remain numerous disputes and challenges regarding its realism, accessibility, and educational efficacy (Bailenson et al., 2006). Some studies have even questioned its applicability and long-term effects in specific educational contexts (Klopfer et al., 2018). Therefore, this research aims to explore in depth the effectiveness of extended reality technologies in the field of education, specifically whether it can provide a more realistic and immersive learning experience.

Aim & Objectives

Aim: The main aim of this study is to delve into the effectiveness of Extended Reality (XR) in education, particularly in terms of whether it can provide a more realistic and immersive learning experience. Objectives: 1. Understand and Define the Fundamental Aspects of XR: Through a review of relevant literature and existing applications, this objective seeks to gain a deep understanding of XR's definition, characteristics, and its application in education. 2. Evaluate XR's Realism and Immersion: Assess how XR can provide lifelike educational experiences by examining system interactivity and virtual learning environments, corroborated by actual case studies. 3. Examine Limitations and Controversies of XR in Education: Investigate the potential drawbacks and contentious aspects of employing XR in education.

Significance

A comprehensive understanding of this issue not only contributes to the advancement of frontier educational technology but also possibly offers valuable practical guidance and decision-making references for educators and policymakers. This study adopts a hybrid method of literature review and case analysis, thoroughly examining existing academic and practical literature, analyzing the definition, characteristics, and application scenarios of extended reality technology, and coupling with actual cases of XR in various educational backgrounds and training environments, to explore the effects and applications of XR in education in an objective and profound way (Wu et al., 2013; Radu, 2014).

Literature Review

In the comprehensive exploration of the effectiveness of Extended Reality (XR) in the field of education, a thorough and diversified literature search strategy was adopted. Considering the interdisciplinary nature of XR technology and its rapidly advancing trends, this study was not confined to retrieving literature from a single database. As such, a broad search was conducted across various databases including ELSEVIER, IEEE Explore, and China's Wanfang Data, also encompassing master's and doctoral theses closely related to the research theme that were published in recent years. To ensure coverage of the latest developments and applications of XR technology, the journals were limited to those published after 2017, and, for reading convenience, only Simplified Chinese and English literature was collected. The choice of search keywords encompassed Extended Reality (XR), Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Immersive Learning, as well as terms related to teaching or training.

In terms of literature selection, we considered not only the novelty and relevance of the literature but also focused on its quality and reliability. Firstly, the influence and recognition by scholars of the literature were assessed through citation counts. Simultaneously, as the citation counts of newly published papers may not adequately reflect their value, we specifically took into consideration the journals where the papers were published, with a preference for papers indexed in SCI. SCI is not just an information retrieval system, but also an important standard for measuring the quality and influence of academic journals. Such selection criteria contribute to ensuring the breadth and depth of the literature review, while also guaranteeing the quality and credibility of the referenced literature.

Definitions

Extended Reality (XR): XR is an umbrella term encompassing virtual, augmented, and mixed reality technologies, as well as other forms of alternate, expanded, or immersive reality applications, including those not yet invented.

The main purpose of XR is to broaden human experiences, especially the senses of existence and the acquisition of cognition (Lokesha & Bhagya, 2020).

XR is an umbrella term that includes the following types of applications:

- Virtual Reality (VR): The application simulates a completely different environment around the user.
- Augmented Reality (AR): The application layers content over a digital view of the real world.
- Mixed Reality (MR): The application combines its own environment with the user’s real-world environment and allows them to interact with each other.

Characteristics of XR

1. Immersiveness

Immersiveness is the most eye-catching feature of XR, with the application of virtual reality being the most prominent. By simulating the real-world environment, learners are immersed in it. Immersiveness helps create a "sense of presence" in the virtual environment, making people feel as if they are truly in the virtual world (Martín-Gutiérrez et al., 2017). Immersive virtual reality enhances learners' engagement and emotional connection, thereby promoting cognitive and emotional learning (Jensen & Konradsen, 2018). Immersiveness provides experiences that cannot be obtained through traditional learning environments, such as immersing in historical scenes or complex scientific concepts.

2. Interactivity

Interactivity is another core element in XR. XR allows learners to interact with the virtual environment through voice, gestures, and touch, receiving learning feedback through interaction with the system. This interaction makes the learning process more natural and intuitive. Interactivity supports collaborative learning and increases learner engagement and dynamic participation (Chen et al., 2017). In virtual experiments or role-playing scenarios, interactivity makes learning more vivid and practical.

3. Personalization

Supporting personalized learning is an important innovative direction for XR technology. As human activities transition from natural to digital platforms, there is a transformation in sensory and practical ways. XR can combine data analysis and artificial intelligence technologies to adapt to different learners' needs and interests. These customized learning paths can promote more effective and in-depth learning. Intelligent teaching systems in virtual environments enhance learning outcomes. With the rise of large models like GPT in recent years, GPT can analyze learners' input and interaction history to understand their interests, knowledge levels, and learning styles, providing personalized content and feedback.

4. Accessibility

Accessibility refers to how XR technology can make educational resources transcend geographical and temporal constraints (Radianti et al., 2020). XR can provide educational opportunities for those in remote areas or unable to attend school in person. Through XR, students can access advanced scientific experimental equipment and museum collections (Merchant et al., 2014). This feature democratizes and popularizes education, making once "out-of-reach" fields like aerospace more "accessible."

5. Interdisciplinarity

XR technology can support interdisciplinary learning, integrating knowledge and skills from different disciplines. XR can enhance learning outcomes for students at all stages and can be applied to multiple subject areas. The potential of XR in promoting interdisciplinary understanding, such as integrating mathematics, science, and art, is significant. Interdisciplinarity helps cultivate students' comprehensive quality and creativity, providing multi-angle perspectives for solving real-world problems.

XR in Education

Extended Reality (XR) as a highly adaptable technology and tool is being actively integrated by many industries to enable rapid pre-job training and quick familiarization for industry newcomers. In the medical field, Ferri et al. (2020) described the experiences of 122 medical students undergoing training with 21 simulated clinical cases online. Most medical students were satisfied with the training and gave it high praise. In the commercial sector, XR can offer "panoramic, zero-distance" capabilities to support virtual office platforms, such as Meta's Horizon Workrooms and Microsoft's Mesh, aiding Human Resources departments in enhancing employees' work lives and virtual collaboration in a 3D environment (Veronica, 2021). Meanwhile, the military field is utilizing virtual reality in interdisciplinary research, including pilot flight simulation and training, mission planning, and rehearsal (Ahir et al., 2020). In culture and tourism, immersive technologies like VR panoramas and AR live tours can tackle the promotional challenges of tourism. Branstrator et al. (2022) created an XR system course based on nature tourism to engage visitors in deeper thinking about biocultural conservation issues.

In the field of education, XR technology is demonstrating unprecedented potential. By creating immersive learning environments, XR provides students with a more vivid, more intuitive learning experience (Wu et al., 2013). For theoretical education, XR can visualize complex concepts, helping students to better understand and grasp them (Merchant et al., 2014). In skills training, virtual reality simulators have been employed for practical training in clinical medicine, aviation, and engineering, offering experiences similar to real environments (Kavanagh et al., 2017). Furthermore, the assessment of learning effectiveness is also a key application area for XR in education. By tracking and analyzing students' interactions within virtual environments, educators can gain in-depth insights into students' understanding and mastery (Radianti et al., 2020). Overall, the application of XR in the educational field provides new dimensions and possibilities for teaching and learning, foreshadowing future trends in education.

With the vigorous development of XR technology, it has been widely applied in the field of education and has demonstrated powerful teaching potential. A large amount of research results show that compared with traditional teaching methods, XR technology can significantly improve learning effects and inject fresh vitality into education. For example, Hu et al. (2021) discovered through comparative experiments that compared with two-dimensional simulation software, the immersive virtual environment of VR can greatly enhance students' practical skills, improve problem solving and self-efficacy, which proves VR's unique advantage in improving learning outcomes. In addition, Hamari et al.'s (2016) research also clearly points out that designing XR games with challenging elements can greatly increase students' learning interest and participation, thus achieving better teaching results. More noteworthy is that an empirical comparison found out that compared with the traditional safety card teaching method, immersive safety education games based on XR can enable learners to acquire better knowledge mastery and long-term memory retention (Chittaro & Buttussi, 2015). It can be seen that XR technology brings an extremely immersive virtual experience to education (Yoo, 2022). Of course, we should also pay attention to the fact that over-reliance on XR may bring higher cognitive load to learners, which needs careful research in order to achieve appropriate application of XR technology in the field of education.

Research Gap

Although technologies such as Extended Reality (XR) and Virtual Reality (VR) are gradually maturing in the field of education, especially making significant progress in immersive learning environments, gamified learning, and special education (Radianti & Wohlgenannt, 2020), there are still many aspects that have not been fully explored. First, although the application of virtual reality technology in basic education has begun to emerge, its implementation cycle is relatively short, and it is mostly carried out in semi-immersive learning environments, lacking comprehensive teaching strategies and effective evaluation systems (Makransky & Mayer, 2019). Secondly, although some important research focuses on the practical application of XR technology in law and basic education, its potential value and actual impact in other specific subject areas have not been fully understood and studied. Additionally, although features such as intelligent interaction and context awareness have been reflected in educational design, how to ensure the effective integration of these new technologies with existing educational systems and educational goals remains an unresolved challenge (Akçayır & Akçayır, 2017).

Case Study

Selection of Cases

In selecting cases for analysis, this study did not deliberately differentiate between various XR technologies (such as VR, AR, MR). This decision is based on the current trend in XR technology development, where the boundaries between individual components are becoming increasingly blurred. For example, Virtual Reality (VR) technology is gradually enhancing its ability to perceive the real world, while Augmented Reality (AR) is striving to provide an immersive experience akin to Virtual Reality. Therefore, this study primarily focuses on cases that maximize the characteristics of immersive experiences, particularly those that employ Virtual Reality (VR) as the main instructional tool. To ensure the comprehensiveness and diversity of the analysis, the selected cases encompass different countries and projects, thereby facilitating the exploration and analysis of the application and impact of XR technology in education from multiple angles and dimensions.

Case 1: The learning content using VR focuses on the fundamental knowledge and basic operations of electronic circuits in electronic technology. In this case study, 53 university students with educational-related majors from a university in Shanghai were selected as subjects. The students in the experimental group learned about the immersive VR experimental environment and became familiar with the corresponding operations through watching videos. Meanwhile, the students in the control group learned about the operation panel of 2D simulation software and became familiar with the corresponding functions through images and text descriptions(Hu et al., 2021). *Case 2*: Virtual reality learning environment using Ignys software to simulate fire scenarios, the training was based on a course document (for conceptual learning) and a VTE (for procedural learning). - 43 people (28 men and 15 women), aged 17 to 29 (A = 20, SD = 3.1) participated in the study. Their training ranged from the end of high school to masters. Most of them were students, the majority of whom had obtained a university degree in health and safety, The participants were divided into two immersion groups, those who were subjected to the condition of immersive environment and those subjected to the condition of non-immersive environment(Morélot et al., 2021). *Case 3*: This case create an activity based virtual reality experience for Thailand’s Ministry of Digital Economy and Society to communicate information covering three topics. The demographic of interest for this study includes all those who participated in the Ministry of Digital Economy and Society’s virtual reality experience during Digital Thailand Big Bang 2019, which was held from October 28th to October 31st, 2019 at the BITEC International Exhibition in Bangkok, Thailand. Convenience sampling was utilized to choose the sample. This yielded a sample size of 126 individuals during the duration of the investigation(Karnchanapayap, 2023).

These three cases provide a wealth of material and diverse perspectives for my research. They encompass a wide range of areas, from university education to vocational training, and extending to government and public communication. Through an in-depth analysis of these cases, it will be possible to comprehensively explore the potential and challenges of XR technology in the field of education.

Analysis Methodology

The analytical framework of this study is based on educational psychology and technology acceptance theory, aiming to comprehensively explore the application of Extended Reality (XR) in education. Educational psychology provides an in-depth understanding of immersive experiences, learning motivation, and cognitive processes. By analyzing how XR technology creates immersive learning experiences, their study reveal how virtual environments can promote students' attention, memory, and understanding (Makransky & Aaby, 2017). Furthermore, technology acceptance theory focuses on the usability and effectiveness of XR technology, as well as the attitudes and behaviors of teachers and students towards new technology. This theoretical framework helps analyze the key factors in people's acceptance and use of XR technology, including its practical contribution to achieving educational goals, and the acceptance and satisfaction of potential users (Davis, 1989; Venkatesh & Davis, 2000). By combining these two theoretical approaches, this case study aims to provide a comprehensive perspective to assess the potential and challenges of XR technology in education, offering profound insights for educators and researchers on how to utilize this emerging technology most effectively.

Based on the reflection and analysis of the above content, the analytical framework for the case study focuses on three core aspects: immersive experience, learning outcomes, and technology acceptance. The immersive experience examines how XR technology creates an immersive learning environment, emphasizing realism and engagement. Learning outcomes concentrate on the impact of XR technology on student motivation, understanding, and academic performance, directly related to educational goals. Technology acceptance explores the usability of XR technology and the attitudes and actual application of teachers and students towards using this new technology. This three-aspect framework provides a solid foundation for this study with its conciseness, comprehensiveness, and flexibility. It clearly covers the key aspects of XR technology in education and easy to understand. However, there may also be an oversimplification of complex interactive factors.

Table 1: Three Core Aspects of the Analytical Framework

Case Study	Immersive Experience (Realism, Engagement, etc.)	Learning Outcomes (Motivation, Understanding, Performance, etc.)	Technology Acceptance (Usability, Attitudes, etc.)
Case 1	Learning basic electronic circuit knowledge through VR experimental environment, 53 university students participated. • VR provides high immersion and interactivity, enhances situational perception • Triggers multisensory integration, enhances sense of presence	• No significant difference in knowledge acquisition between VR and 2D environments • VR significantly improves behavioral transfer, promotes skill transfer and problem solving • Enhances self-efficacy and deep learning	• VR leads to higher cognitive load and physiological discomfort • But learners have higher acceptance of VR technology

Case 2	Virtual reality learning environment using Ignys software to simulate fire scenarios, 43 participants. • Head-mounted displays and other devices increase sense of immersion • Life-size models of fire facilities enhance scene realism • Dynamic smoke and flame simulation improve situational perception	• The immersive environment improved procedural learning outcomes, but did not help conceptual learning • Prior knowledge in fire safety can enhance the facilitation effect of immersion on procedural learning	Technology acceptance was not measured in this study
Case 3	Activity-based virtual reality experience created for Thailand' s Ministry of Digital Economy and Society, 126 participants. • Oculus Quest head-mounted device provided immersive sense of presence • Minimalist design of the virtual environment	• Activity-based design enhanced audience participation and content comprehension • Most participants were able to correctly answer questions, indicating retention of content	• Majority appreciated the overall experience and aesthetics • A few were dissatisfied due to nausea and other issues

Key Insights From Cases

Case 1: The VR experimental environment is conducive to the cultivation of operating skills and cognitive transfer of basic electronic circuit knowledge. However, it needs to balance cognitive load and deep learning during the design process. Overall, VR has promising application prospects in engineering experimental teaching, especially in terms of problem solving and skills training. But the design of VR experimental environment should take cognitive load factors into consideration, and try to provide learners with a smoother and more comfortable learning experience. *Case 2*: The immersive VR environment using Ignys software improved procedural learning outcomes of fire safety training. But it showed no benefit for conceptual learning. Prior knowledge in fire safety can enhance the facilitation of immersion on procedural learning. The technology acceptance was not measured in this study. *Case 3*: The activity-based VR experience created for Thailand's Ministry of Digital Economy and Society increased audience engagement during the exhibition. Most participants actively took part in the experience and retained its content. While the majority appreciated the overall experience, a few suffered discomfort. This case study exemplified how VR can enhance audience participation through activity design.

Comparison and Contrast: These three case studies demonstrate the unique advantages of virtual reality technology in providing an immersive sense of presence and enhancing learning effectiveness. Case 1 and Case 2 both found that compared to conceptual learning, virtual reality environments have more significant effects on improving procedural learning and skills training. In these two cases, learners also showed higher acceptance of virtual reality technology, but negative impacts like increased cognitive load also occurred. Case 3, as an application of virtual reality technology in an exhibition scenario, has its own uniqueness with more focus on learning experience rather than learning outcome evaluation.

Key Findings: Through these three case studies, it can be discovered that virtual reality technology can enhance the experience of learning by providing an immersive sense of presence and designing participative activities. But its effects seem more prominent in improving procedural learning and skills training, while the impact on conceptual learning is more limited. In addition, virtual reality can also facilitate deeper learning, but brings cognitive load as well, which needs balancing between the two. Overall, virtual reality technology has extensive application prospects in fields like engineering experimental teaching, safety training, and audience engagement in exhibitions.

Conclusion

Main Findings

This study has shown that extended reality (XR) technologies, especially virtual reality (VR), can provide more realistic and immersive learning experiences compared to traditional educational methods. The literature review revealed XR's key characteristics of immersiveness, interactivity, personalization, accessibility, and interdisciplinarity that enable vivid simulated environments and active student participation. Case studies demonstrated VR's advantages in improving procedural learning and skills training by increasing engagement and situational presence.

However, XR's effects on conceptual learning appear more limited. While most learners expressed acceptance towards VR technology, issues like increased cognitive load were also identified. This research implies that for engineering, safety training, and public engagement, VR has promising applications to enhance experiential learning. But conceptual subjects may require different strategies. Overall, XR holds significant potential to transform education, but optimal integration with curriculum and balanced design are crucial.

Implications and Limitations

This study provides valuable practical implications for educators and policymakers in leveraging XR, particularly VR technology, to modernize pedagogy. The research recommends designing highly interactive activities, adapting to individual needs, and balancing cognitive load to maximize XR's advantages while minimizing discomfort. However, there are limitations. The case analyses focused narrowly on VR without equal inclusion of AR and MR. The sample sizes were small and lacked diversity. Future studies should investigate a broader range of XR applications across diverse subjects, ages, and backgrounds. More objective measurements of learning effectiveness are also needed. With further research and thoughtful implementation, XR could greatly benefit students worldwide through more captivating, participatory, and personalized learning.

References

Ahir, Govani, K., Gajera, R., & Shah, M. (2020). Application on Virtual Reality for Enhanced Education Learning, Military Training and Sports. *Augmented Human Research*, 5(1).

Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 27, 253-276.

Bailenson, J. N., Yee, N., Merget, D., & Schroeder, R. (2006). The effect of behavioral realism and form realism of real-time avatar faces on verbal disclosure, nonverbal disclosure, emotion recognition, and copresence in dyadic interaction. *Presence: Teleoperators and Virtual Environments*, 15(4), 359-372.

Branstrator, J. R., Cavaliere, C. T., Xiong, L., & Knight, D. (2022). Extended reality and sustainable tourism: restorying human-wildlife relationships for biocultural conservation. *Journal of Ecotourism*, ahead-of-print(-), 1-17.

Chang, C. Y., Lai, C. L., & Hwang, G. J. (2018). Trends and research issues of mobile learning studies in nursing education: A review of academic publications from 1971 to 2016. *Computers & Education*, 116, 28-48.

Chen, P., Liu, X., Cheng, W., & Huang, R. (2017). A review of using Augmented Reality in Education from 2011 to 2016. *Innovations in smart learning*, 13-18.

Cheng, K. H., & Tsai, C. C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of science education and technology*, 22, 449-462.

Chittaro, L., & Buttussi, F. (2015). Assessing knowledge retention of an immersive serious game vs. a traditional education method in aviation safety. *IEEE transactions on visualization and computer graphics*, 21(4), 529-538.

Chu, L., Chen, W., Tan, Y., et al. (2019). Reshaping Experience: Prospects of Extended Reality (XR) Technology and Its Educational Applications — A Discussion on the Integration of Education and New Technology. *Journal of Distance Education*, 37(1), 17-31.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319-340.

Ferri, Grifoni, P., & Guzzo, T. (2020). Online Learning and Emergency Remote Teaching: Opportunities and Challenges in Emergency Situations. *Societies (Basel, Switzerland)*, 10(4), 86.

Fowler, C. (2015). Virtual reality and learning: Where is the pedagogy? *British journal of educational technology*, 46(2), 412-422.

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in human behavior*, 54, 170-179.

Hu, Y., Nie, J., Zhang, T., et al. (2021). Exploration of the Effects of VR Technology Empowering Experimental Teaching from the Perspective of Embodied Cognition. *Journal of Modern Distance Education Research*, 33(5), 94-102.

Illeris, K., & Ryan, C. (2020). Contemporary theories of learning: Learning theorists... in their own words. *Australian Journal of Adult Learning*, 60(1), 138-143.

Jang, S., Vitale, J. M., Jyung, R. W., & Black, J. B. (2017). Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment. *Computers & Education*, 106, 150-165.

Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 23, 1515-1529.

Johnson, L., Becker, S. A., Cummins, M., Estrada, V., Freeman, A., & Hall, C. (2016). *NMC horizon report: 2016 higher education edition* (pp. 1-50). The New Media Consortium.

Kavanagh, S., Luxton-Reilly, A., Wuensche, B. & Plimmer, B. (2017). A systematic review of Virtual Reality in education. *Themes in Science and Technology Education*, 10(2), 85-119. Retrieved August 10, 2023 from https://www.learntechlib.org/p/182115/.

Karnchanapayap, G. (2023). Activities-based virtual reality experience for better audience engagement. *Computers in Human Behavior*, 146, 107796.

Klopfer, E., Haas, J., Osterweil, S., & Rosenheck, L. (2018). *Resonant games: Design principles for learning games that connect hearts, minds, and the everyday*. MIT Press.

Lokesha, V. B., Banumathi, D., & Bhagya, R. (2020). Progressing with extended reality. *Journal of Critical Reviews*, 7(18), 1405-1411.

Makransky, G., Lilleholt, L., & Aaby, A. (2017). Development and validation of the Multimodal Presence Scale for virtual reality environments: A confirmatory factor analysis and item response theory approach. *Computers in Human Behavior*, 72, 276-285.

Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and instruction*, 60, 225-236.

Martín-Gutiérrez, J., Mora, C. E., Añorbe-Díaz, B., & González-Marrero, A. (2017). Virtual technologies trends in education. *Eurasia journal of mathematics, science and technology education*, 13(2), 469-486.

Merchant, Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers and Education,* 70, 29–40.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995, December). Augmented reality: A class of displays on the reality-virtuality continuum. *In Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282-292). Spie.

Morélot, S., Garrigou, A., Dedieu, J., & N'Kaoua, B. (2021). Virtual reality for fire safety training: Influence of immersion and sense of presence on conceptual and procedural acquisition. *Computers & Education,* 166, 104145.

Prensky, M. R. (2010). *Teaching digital natives: Partnering for real learning*. Corwin press.

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

Radu, I. (2014). Augmented reality in education: a meta-review and cross-media analysis. *Personal and ubiquitous computing*, 18, 1533-1543.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science,* 46(2), 186-204.

Veronica Combs,. (2021). The metaverse: What is it? *Techrepublic.* Retrieved August 10, 2023, from https://www.techrepublic.com/article/metaverse-what-is-it/

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, 62, 41-49.

Yoo, H., Jang, J., Oh, H., & Park, I. (2022). The potentials and trends of holography in education: A scoping review. *Computers & Education*, 186, 104533.

Contact email: 2104582@student.uwtsd.ac.uk