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Editorial: Working mechanisms of design elements to facilitate learning in extended reality

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Editorial on the Research Topic
Working mechanisms of design elements to facilitate learning in extended reality

Introduction

Over the past decade, extended reality (XR), including virtual reality (VR), augmented reality (AR), and mixed reality (MR), has emerged as a powerful tool for immersive and interactive learning. While its benefits are widely acknowledged, identifying the design mechanisms that effectively facilitate learning remains a key research challenge. This Research Topic of Frontiers in Virtual Reality titled "*Working Mechanisms of Design Elements to Facilitate Learning in Extended Reality*" brings together five studies that investigate critical factors influencing learning in XR. The research addresses themes such as Immersive Interaction and Embodiment, Adaptive and Personalized Learning, and Co-Creative Design and Intelligent Virtual Agents, offering new insights into how XR environments can be optimized for meaningful educational outcomes.

Immersive interaction and embodiment

This section focuses on immersive interaction and embodiment, featuring two articles. Rehren et al. in "*Task-related errors as a catalyst for empathy towards embodied pedagogical agents*" explored how task-related errors made by virtual pedagogical agents in XR could catalyze learners' empathy. Their study showed that when errors were strategically designed, they increased engagement and fostered a stronger connection between learners and virtual agents, ultimately improving learning experiences and outcomes. Palombo et al. in "*Glove versus controller: the effect of VR gloves and controllers on presence, embodiment, and cognitive absorption*" investigated the impact of different input devices (i.e., VR gloves versus controllers) on users' sense of presence and embodiment. Their findings emphasized how haptic feedback and naturalistic interactions contributed to immersion, underscoring the importance of interface design in XR education. Together, these articles highlight the significance of intentional error design and interface innovation in enhancing engagement and immersion.

Adaptive and personalized learning

This section focuses on adaptive and personalized learning through the article "*Features of adaptive training algorithms for improved complex skill acquisition*" by Verniani et al. The authors investigated how adaptive training algorithms could support the acquisition of complex skills in XR environments. Their findings demonstrated the potential of real-time adjustment and dynamic feedback to enhance learning outcomes, particularly in high-stakes domains such as aerospace, medicine, and technical training. This study underscores the importance of tailoring XR experiences to individual learners' needs and performance, making personalization a key mechanism for increasing training efficiency and relevance.

Co-creative design and intelligent virtual agents

This section focuses on co-creative design and intelligent virtual agents, featuring two articles. Retz et al., in "*CIEMER in action: from development to application of a co-creative, interdisciplinary exergame design process in XR*" analyzed the role of participatory design in the development of XR-based exergames. Their findings showed that interdisciplinary collaboration can significantly enhance the relevance and engagement of educational tools. Graf et al. in "*Towards believable and educational conversations with virtual patients*" investigated how conversational realism and adaptability in virtual patients could improve medical training. Their results emphasized the potential of intelligent agents to bridge the gap between theoretical instruction and practical application.

Cross-paper synthesis and limitations

Taken together, the five contributions reveal how specific XR design features—strategic error design, embodied interaction, real-time adaptation, participatory development, and agent realism (the believability of virtual characters)—jointly shape learners' experiences and contribute to educational effectiveness. The articles reflect a shared focus on refining design elements that foster immersion, personal relevance, and experiential learning in XR education. This synthesis suggests that successful XR-based learning environments are those that actively align design mechanics with pedagogical goals across diverse domains.

As with all research, certain limitations must be acknowledged. The studies in this Research Topic are context-specific and often rely on controlled experimental setups or prototype systems. Future research should aim to test the generalizability of these findings across varied educational contexts and longer-term usage scenarios.

Implications for future research and practice

The findings presented in this Research Topic have significant implications for both future research and practice in XR education. They underscore the need for continued exploration of how design mechanisms influence learning in immersive environments. By applying these insights, educators and developers can craft more personalized, engaging, and effective XR learning experiences.

We hope this Research Topic will serve as a valuable resource for researchers, educators, and practitioners seeking to deepen their understanding of how XR design elements support engaging and effective education.

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Conflict of interest

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