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Guest Editorial: Learning Experience Design: Embodiment, Gesture, and Interactivity in XR

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ABSTRACT: The concepts of embodiment and embodied learning are gaining traction in the field of education. This special issue aims to synthesize current knowledge on the design and evaluation of learning in immersive and embodied learning environments, mediated by XR (eXtended Reality) technologies. Of the 14 invited submissions, six (6) were finally accepted for publication. The collection of works in this special issue provides insights on best practices for learning experience design, based on systematic or empirical data and analysis on learning outcomes or processes.

Keywords: XR, AR, VR, MR, Extended reality, Virtual reality, Augmented reality, Mixed reality, Embodied learning, Immersive learning, Learning environments

1. Introduction

The concepts of embodiment and embodied learning, deeply rooted in theories of embodied cognition, are gaining traction in the field of education. New educational technologies enable researchers and practitioners to include more gestures and body movements into their learning experience design, creating immersive and gesture-rich learning environments. Such embodied environments should enable multi-modal and multi-sensory forms of interaction through gestures and bodily movement, tactile, and auditory sensory experiences. While the interplay of new forms of technology and learning is complex, recent evidence suggests that learning experience design, pedagogy, and practice with embodied and immersive learning technologies can have important effects on learning, engagement, and achievement in multiple educational settings, including formal and non-formal (Georgiou & Ioannou, 2019). This special issue aims to synthesize current knowledge on the design and evaluation of learning in immersive and embodied learning environments.

The specific scope of this special issue is to publish research that addresses learning in immersive and embodied environments mediated by XR (eXtended Reality) technologies, an umbrella term that refers to the spectrum of AR, VR, and mixed-reality environments, immersive gaming environments, immersive escape rooms, XR mobile computing platforms, etc. The focus of this special issue is not the technology per se but rather issues related to learning experience design (or learning design), the process continuum of teaching, learning and assessment, and how these are affected or enhanced by XR technologies. We have sought out evidence-based educational applications and research that meshes pedagogy and practice in all types of learning environments. Indeed, empirical research on the intersection of pedagogy and practice of XR learning in authentic settings is very limited to date. The aim of this special issue is to provide insights on best practices for learning experience design, based on systematic or empirical data and analysis on learning outcomes or processes.

The initial call for paper proposals resulted in 40 high caliber mini prospectuses, of which 14 were invited to submit full papers. All the invited submissions underwent ET&S's rigorous blind peer review process, with over 30 field specialists from around the world agreeing to provide expert reviews. Of the 14 invited submissions, six (6) were finally accepted for publication. The editorial team allowed the more robust and well-developed submissions to be processed for publications after two rounds of revisions and extensive work by the authors and reviewers to ensure high quality.

2. Overview of papers

The variety of technologies, research methods, and research contexts in our collection of papers allows the reader of this special issue to gain a comprehensive insight into the current state-of-the-art in learning experience design in XR.

Kang, Diederich, Lindgren and Junokas (2021) focus on gesture patterns and learning in an embodied XR science simulation. The innovative ELASTIC3S system allows learners to interact with different science simulations via whole-body gestures (e.g., hand waving, kicking). The authors found trends in the use of the science simulations directly linked to students' struggles in understanding the underlying ideas or use of the system, as well as with their learning performance. Their findings can inform the design of the real time assistance within the embodied simulation, thus enabling an adaptive learning experience.

In their work, Birt and Vasilevski (2021) examine immersive VR learning in the context of building information modeling (BIM) in architecture, engineering, and construction. The researchers experimented with a multiuser (synchronous and collaborative) vs. a single-user (asynchronous) learning environment and found that the learners' experience was better in the multiuser condition. Considering these findings, the authors discuss the future design of immersive virtual reality environments for learning.

Holly, Pirker, Resch, Brettschuh and Gütl (2021) elaborate on the challenging job of designing educational VR platforms to meet the expectations of educators and students. The reflections are the result of the authors' work on the Maroon platform -- a VR environment for teaching physics -- which has been in development for over five years. The authors present recommendations related to immersion, costs, time restrictions, and the learning process to overcome current challenges for learning and teaching with VR in the physics domain.

In their work, Lyons and Mallavarapu (2021) take a new approach to understand VR immersive experiences. They define the concept of collective usability, as the degree to which a group of simultaneous users can make use of an interactive experience where the human-computer and human-human interactions combine to form a complex system. The authors present a simple agent-based model simulation to explore how changes in the number of simultaneous users and the duration, size, and number of the proffered interactives can affect the collective usability of XR learning environments.

Chaker, Binay, Gallot and Hoyek (2021) examine the user experience of the learners in a 3D interactive human anatomy tool. The paper presents the author's research and development approach, which includes two phases of data collection and UX evaluation. The authors found a correlation between student's UX and both their anatomy scores and motor imagery abilities (i.e., their ability to imagine a human movement without any real movement).

Yiannoutsou, Johnson and Price (2021) extend the discussion of the pedagogical design of embodied mathematical experiences for visually impaired children. They present an iterative, design-based case study with visually impaired children to inform the pedagogical design of embodied mathematical experiences. Their system provides opportunities for grounding mathematical ideas in audition and bodily experience. In their work, sensorimotor interaction (e.g., touching a small tangible grid to understand how to then locomote in an auditorily enhanced CAVE with grid-like components) seems particularly promising for visually impaired children. Their findings show how bodily movement and positioning can effectively foster visually impaired children's engagement, and they discuss prerequisites for the implementation of immersive VR in the classroom.

3. Summary and future directions for XR learning experience design research

XR in education has great potential for research and development. XR technologies can be integrated in the learning environment to allow learners to interact with critical elements in a domain without real risk; it can make the "unseen be seen" in ways that 2D media cannot. Using XR technologies, one may enable simulated environmental and socio-cultural interactions between students, educators, practitioners, patients, workers, or other stakeholders in a safe learning environment that authentically simulates the situation, the risks, and the opportunities for action. This special issue aimed to publish state-of-the-art research that uses the principles of embodied cognition meshed with the affordances of XR to engage learners and promote learning outcomes in formal and informal learning environments.

This special issue has compiled research in this burgeoning area; however, it only contributes a small sample of research in the area of learning experience design in XR learning environments. Namely, while this special issue addresses different learners (i.e., high school students, special education) and types of educational context (STEM classroom, design, physiology), there is still a need for more studies. For example, these studies might include younger students, use a larger variety of formal and informal learning situations, different research domains (e.g., humanities and empathy induction), and perhaps explore the boundaries of interactivity in three dimensions (e.g., where is the tipping point for too much interactivity such that it becomes overwhelming for the learner? What are best scaffolding methodologies?). Moreover, in the scope of learning experience design in XR learning environments, the technologies presented in the various contributions of this special issue include VR environments and 3D simulations of low to medium immersion according to the Johnson-Glenberg taxonomy of embodiment in education (2018). We note that XR also includes mobile AR/VR and highly immersive virtual, augmented, and mixed reality environments. The technology is available (e.g., Hololens) to exploit for the design of highly immersive learning environments using overlays, and several companies are now releasing easy-to-use or “no-code” editors for AR and in-headset VR experiences. Educators are encouraged to experiment with these editors and technologies that allow students to be creators in their classrooms.

In terms of methods, there are both quantitative and qualitative studies in this special issue. The editors would suggest that Design-Based Research (DBR) is a promising methodology to support researchers in the advancement of XR learning design in these early stages of work and experimentation (e.g., Ioannou & Ioannou, 2020). DBR shifts the focus to the design problem or learning need and should help researchers examine the appropriate use of XR technologies to address learning needs. DBR can lead to theoretical understanding and transferable design principles for promoting learning in XR learning environments beyond the context of a particular learning need. Such theoretical understandings or transferable design principles illustrating how XR can enrich the learning environment would help researchers and practitioners communicate with each other and advance XR learning design.

This special issue is a concrete step in uniting the divergent XR and learning communities; it also raises many questions. Some of the studies included in this special issue are still in the early stages and there is undoubtedly much space for extending the work of these authors. Evidently, there is a need for more research that will continue to contribute to the growing empirical literature on learning experience design, pedagogy, and practice with embodied and immersive XR technologies. A framework for XR learning design focused on presenting design principles for learning in XR environments becomes of paramount importance as XR technologies continue to make their way into formal and informal educational settings. Moreover, well-researched developments in this area should begin to find their way to commercialization so that more researchers and practitioners can benefit from using them. As evident in the manuscripts of this special issue, the design, development, and evaluation of XR learning environments is a very demanding job and studies are rarely “perfect.” Leaving these developments on the shelves of research laboratories does not help with the wide dissemination and adoption of important findings in teaching and learning. The opportunities and expected outcomes for the learners can be immediately realized when such developments become commercially available, especially at low cost or for free, and easily accessible to those who might be looking to adopt innovative solutions for teaching and learning. We hold that, XR learning experience design is a fruitful area for research and development going forward. The editors of this special issue hope that this introduction and the six contributions that follow will provide a starting point for further inquiry in this area.

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