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Guest editorial: Special issue on "disruption, innovation and resiliency in immersive learning"

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Immersive learning applications have become increasingly popular in recent years as they offer users a more engaging and interactive learning experience. However, many definitions of "immersion" and "Immersive Learning" still exist, and we need consensus on how to apply them. We use the definition adopted by the Immersive Learning Research Network, which views immersion as a phenomenon with three dimensions: technical, narrative, and agency and an "immersive learning environment" as the surroundings where immersion develops (Beck et al., 2020, p. 1043).

Immersive learning environments have the potential to improve learning, augmenting conventional teaching methods towards the creation of engaging experiences for learners. However, there are still many challenges in designing meaningful experiences that address pedagogical needs (Beck et al., 2023) whilst considering current technology affordances to ensure that these experiences consolidate into well-established learning tools that are scalable and correctly assessed. Moreover, the interdisciplinary nature of these applications has created new bridges between researchers, computer scientists, educators, gamers, UI/UX designers, and developers while considering ethics and best practices, developing the field of Immersive Learning research.

In this regard, the Immersive Learning Research Network (iLRN) (https://immersivelrn.org/) has been working on creating and supporting a community for the different disciplines involved in creating immersive learning experiences towards

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developing the scientific, technical, and applied potential of immersive learning. Moreover, iLRN has challenged the community towards the systematization of this field with the Immersive Learning Knowledge Tree initiative, bridging their different epistemological landscapes to combine their efforts and develop the field of immersive learning research.

For all the reasons previously stated, we are glad to present this special issue on "Disruption, Innovation and Resiliency in Immersive Learning" as a way to provide a common theme for scientists, practitioners, organizations, and innovators across disciplines to share their research findings, experiences, and insights on the emerging scholarly knowledge base on how these technologies can be used to create experiences that educate, engage, and excite learners towards shaping the future immersive technologies for learning. This special issue was organized in collaboration with the Immersive Learning Research Network (iLRN) as a follow-up from their 8th annual International Conference (iLRN2022). The 8th annual International Conference of the Immersive Learning Research Network (iLRN2022), held between May 30 and June 4, 2022, offered two days of presentations and activities on the iLRN Virtual Campus (powered by ©Virbela), followed by three days on location at the FH University of Applied Sciences BFI in Vienna, Austria.

This special issue consists of 17 papers that followed a rigorous peer-review process following the Education and Information Technologies journal's high standards (43.60% acceptance rate). The special issue accepted open submissions from the wider community and extended contributions from the iLRN2022 conference (with at least 50% new material). All contributions were independently evaluated in a double-anonymized review process and checked for plagiarism to ensure the authors followed the requirements.

The articles presented in this special issue highlight the benefits and challenges of technologies and pedagogies for immersive learning in different educational contexts, from 360° videos and 3D models to virtual and augmented reality implementations combined with haptic interfaces, sensors and electroencephalogram (EEG) devices to read biometric responses in game-based learning scenarios for science, medical and art education training.

The first article, by Philipp Rosendahl and Ingo Wagner, discusses the potential of 360° videos as a teaching and learning medium, highlighting their unique advantages such as immersion, panoramic views, multi-perspective options, and interaction possibilities. The study identifies three primary purposes for using 360° videos in education: presentation and observation of content, immersive theory–practice mediation, and external and self-reflection. Additionally, the text outlines five added value categories for using 360° videos, including increased learning motivation, authentic learning scenarios, immersive and interactive experiences, multi-perspective observation, and individualized learning. The overall findings emphasize positive motivational effects for authentic and immersive learning experiences.

The second article, by Maria Emine Nylund, Shubham Jain, Eva Tegnander, Eva Johanne Leknes Jensen, Ekaterina Prasolova-Førland, Frank Linsdeth and Gabriel Kiss, introduces a mixed reality (MR) application designed to enhance training in performing pulsed-wave Doppler ultrasound, a common technique in monitoring pregnancies. The complexity of this procedure and the need for access to advanced

equipment and expert supervision make training challenging. Expert feedback and user-testing results were gathered to validate the application's purpose and effectiveness in assisting in both simulated and real-life ultrasound procedures. The study contributes to leveraging immersive environments for medical training and practice to enhance ultrasound training efficiently.

The third article, by Sharon Pisani, Alan Miller and Mark Hall, discusses the transformation of experiencing cultural heritage from traditional museum exhibitions to the digital realm, restoring artifacts and creating authentic replicas of their original states using digital tools, such as 3D scanning and digital modeling techniques. The study uses 3D models of Pictish sculptures as a case study, offering diverse interpretation opportunities inside and outside the museum via a tour in the virtual environment. The digitized objects serve as a means of informal learning, and findings from an evaluation session indicate that participants enjoyed the immersive learning experience and willingness to learn more about the topic.

The fourth article, by George Koutromanos, Anastasios T. Mikropoulos, Dimitrios Mavridis and Christos Christogiannis, explores factors influencing pre-service and in-service teachers' intention to use Mobile Augmented Reality (MAR) in teaching, proposing the Mobile Augmented Reality Acceptance Model (MARAM). MARAM extends the Technology Acceptance Model (TAM) by adding components like perceived relative advantage, perceived enjoyment, facilitating conditions, and mobile self-efficacy. The study suggests implications for MAR in research and schools and technology acceptance models in education.

The fifth article, by John Barrow, William Hurst, Joakim Edman, Natasja Ariesen and Caspar Krampe, describes a pilot study investigating the effectiveness of virtual reality (VR) in biochemistry education at the undergraduate level. Participants used VR headsets and electrodermal activity (EDA) sensors to learn the steps of the citric acid cycle in a virtual lab through eight levels of activities. Post and pre-surveys, along with EDA readings, were conducted to assess the impact of VR on students' understanding, supporting the hypothesis that VR enhances students' comprehension, especially when they feel engaged and stimulated and intend to use the technology. This innovative approach leverages biometric data to measure learner engagement and to link it with a deeper understanding of the subject matter.

The sixth article, by Carl Boel, Tijs Rotsaert, Martin Valcke, Alexander Vanhulsel and Tammy Schellens, examines and deliberates upon the integration of Educational Design Research fortified by gamification in creating a low-cost, mobile VR game tailored for secondary vocational students preparing to navigate hazardous conditions. The authors offer an empirical exploration, evaluating the design components within this educational resource. The text discusses the challenges faced by students in secondary vocational education who need to learn and practice skills in potentially dangerous situations. The study also identifies critical design elements through iterations, discusses them in detail to assist researchers and practitioners in designing immersive VR learning experiences, and concludes with suggestions for future research directions.

The seventh article, by Hayoung Jeon, Yumi Jun, Teemu H. Laine and Eunha Kim, discuss the development and evaluation of an immersive VR game designed to enhance cognitive empathy by helping individuals recognize and accept different

perspectives and feelings in a given situation. The game involves solving puzzles based on ambiguous images and 3D models. The findings present a valuable resource for designers, developers, researchers, and psychologists interested in VR-based empathy education.

The eighth article, by Iris Lim, explores using a neuroscience-themed physical escape room as a game-based learning strategy to teach soft skills, such as team dynamics, problem-solving and critical thinking, to undergraduate biomedical or health science students. The findings suggest that the escape room, in a short period, effectively encourages students to utilize communication and teamwork skills, offering a fun and engaging experience that enhances soft skills learning.

The ninth article, by Eileen McGivney, Tessa Forshaw, Rodrigo Medeiros, Mingyue Sun and Tina Grotzer, investigated the impact of a job interview VR simulation on the emotions, confidence, and self-efficacy beliefs of jobseekers whom the criminal justice system has impacted. The study suggests that a VR job interview simulation tailored to the experiences of people impacted by the criminal justice system can alleviate some of the emotional toll the job search takes on this vulnerable population.

The tenth article, by Fazlida Dahalan, Norlidah Alias and Mohd Shahril Nizam Shaharom, conducted a Systematic Literature Review to map the emerging trends of gamification and game-based learning (GBL) in the Vocational and Education Training (VET) sector. The findings support the conclusion that gamification and game-based learning can improve vocational education learners' academic performance, engagement, and motivation.

The eleventh article, by Xiaozhe Yang, Pei-Yu Cheng, Xin Liu and Sheng-Pao Shih, compares immersive learning against conventional 2D interactive materials using biometric data, shedding light on analogous findings within this educational context. The paper introduces a new art metaverse prototype utilizing VR technology to create an immersive scene with a specific artistic style. The prototype enables interaction with characters resulting in a more positive impact on their art attitude than the computer group. EEG attention monitoring during the subsequent art painting activity showed that the VR group exhibited significantly higher attention levels than the computer group. The study echoes the discoveries akin to Barrow et al., suggesting the potential of VR technology to enhance art education and provide insights for future development in this domain.

The twelfth article, by Nur Azlina Mohamed Mokmin and Regania Pasca Rassy, discusses using augmented reality (AR) technology in education, focusing on students with learning difficulties, specifically in physical education. Physical education is identified as a challenging subject for students with learning disabilities. The study aims to provide clear insights into the evolving role of AR technology in physical education for students with learning difficulties and contribute to further advancements in this area.

The thirteenth article, by Xining Wang, Gareth W. Young, Muhammad Zahid Iqbal and Conor Mc Guckin, addresses the potential benefits of extended reality (XR) for rural educators who often encounter limited resources and low job satisfaction. The findings suggest that educators see XR as a transformative tool that can reshape traditional educational practices and open up new possibilities for rural education, includ-

ing public engagement with rurality and vocational education. However, limitations include more school infrastructure for XR implementation and a well-structured curriculum design for XR in classrooms.

The fourteenth article, by Shufan Yu, Qingtang Liu, Jiaxu Liu, Jingjing Ma and Yuanyuan Yang, used AR to help students learn about the Doppler effect, a topic in acoustics and examines its educational effectiveness in comparison to a two-dimensional (2D) learning tool. Results indicate that students in the AR group performed better in learning achievement and showed more interest than those in the 2D group. Both groups expressed a positive attitude toward the Doppler class and physics learning. Additionally, students demonstrated a high level of cognitive perception toward the AR learning tool. The study suggests the potential and effectiveness of AR technology in enhancing acoustics learning.

The fifteenth article, by Binbin Qi, Muhua Zhang, Xuefang Zhu, Yanshuang Jiang and Xin Xiang, delves into the efficacy of haptic interaction in museum learning. Their exploration unveils the outcomes from a comparative study between haptic and non-haptic interfaces for arts and social science students. This investigation highlights haptic interaction in learning and its potential for amplifying information processing, elevating psychological immersion, profoundly captivating learners and fostering heightened engagement.

The sixteenth article, by Serkan Solmaz, Liesbeth Kester and Tom Van Gerven, discusses the integration of VR into engineering education and training, emphasizing its cognitive and behavioral benefits in overcoming students' difficulties with complex concepts such as computational fluid dynamics (CFD). CFD simulations are widely used in chemical engineering, but their implementation in education poses challenges for students and lecturers. This study identifies features to enhance the quality of the VR experience, and practical implications are provided to guide developers and practitioners in incorporating VR effectively into engineering education.

The seventeenth article, by Xiang bin Qiu, Cheng Shan, Jin Yao and Qing Ke Fu, reports on a meta-analysis conducted to compare the effectiveness of VR-based English as a foreign language (EFL) learning methods with traditional EFL learning methods. The study examined moderating factors, finding significant differences in educational levels, country/area, and EFL learning outcomes among the samples. The article provides recommendations for optimizing VR-based EFL learning, including suggestions for learning outcomes, educational stages, learning materials, and VR types. The findings aim to guide future research and practical applications in this field.

Overall, we believe that the articles included in this special issue illustrate the multiple opportunities for innovation in immersive learning. This volume provides the community with timely opportunities to discuss research and innovation in this strategically important area, presenting an exciting window to the challenges and new developments that immersive learning poses, clearly represented in this special issue.

We are grateful to authors and reviewers for contributing to this special issue. We hope this publication will be a valuable resource for scholars, practitioners, and researchers in immersive learning and inspire future discoveries and innovations in our exciting and rapidly evolving field. If you are not already involved, we invite you to read this special issue and join us in our subsequent events and ongoing initiatives.

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