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Navigating the Terrain:
Emerging Frontiers in Learning Spaces, Pedagogies, and Technologies

Bridging the Visualization Gap: The Integrated VR Educational Technology Assessment (IVRETA) Framework for Enhancing Educational Technologies

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The integration of three-dimensional (3D) modelling tools in educational settings promises a transformative shift in teaching complex concepts. Despite their potential, the actual deployment of such tools faces substantial pedagogical and technical challenges, primarily due to the "visualization gap" between traditional 2D resources and 3D constructs. This gap can significantly hinder students' understanding and retention of complex spatial concepts critical in disciplines such as medicine, engineering, and architecture. To address these challenges, this paper introduces the Integrated VR Educational Technology Assessment (IVRETA) framework, designed to evaluate and guides the development of virtual reality (VR) and augmented reality (AR) tools in education. IVRETA assesses tools across three dimensions: Interaction and Usability, Learning Enhancement, and Authentic Pedagogy and Adaptability. Applying this framework, we evaluate 3D Whiteboard, a practical tool designed to facilitate dynamic interaction with 3D models and enhance educational outcomes through immersive learning experiences. The paper underscores the potential of the 3D Whiteboard in bridging the visualization gap and improving educational practices across various disciplines, *demonstrating how IVRETA can guide the assessment and improvement of educational technologies*. By providing a robust foundation for the development and enhancement of educational technologies, IVRETA supports ongoing innovation in educational settings.

Keywords: 3D modelling tools, educational technology, virtual reality (VR), augmented reality (AR), immersive learning, educational frameworks, 3D annotations

Introduction

The integration of 3D modelling tools into educational settings has revolutionised the way complex concepts are taught across diverse disciplines ranging from medicine and engineering to chemistry and architecture (Gurses et al, 2024; Halabi, 2020). Despite their potential, the integration of three-dimensional learning tools often encounters significant pedagogical and technical challenges that can block their effectiveness (Lege & Bonner, 2020). A significant challenge is the visualization gap between 2D resources and 3D spatial educational resources, hindering understanding of complex structures in disciplines where precision and spatial accuracy are critical (Asad et al., 2021). While real-world interactions could bridge this gap by providing tangible understanding, they often involve high costs, safety risks, and logistical constraints like handling hazardous chemicals or accessing rare artifacts.

Historically, educational methods have relied heavily on 2D diagrams and textual descriptions to convey concepts that are inherently spatial and dynamic. However, this traditional approach often falls short, as students struggle to translate flat representations into volumetric understandings necessary for effective application and analysis. The discrepancy between what is depicted in a 2D diagram and what is envisioned in a 3D space creates a cognitive disconnect that can hinder learning and retention (Ioannou, 2023) Overcoming this challenge requires not only innovative educational tools that can bridge these representational gaps but also effective learning strategies that can enhance comprehension and engagement (Hanid et al, 2020)

Furthermore, educators across disciplines face significant challenges in explaining complex 3D concepts through conventional 2D methods. The static nature of 2D materials fails to capture the dynamic possibilities inherent in many fields, where understanding the interplay of dimensions, movements, and interactions is crucial. These educational challenges call for a dynamic and interactive approach to teaching and learning, which can be facilitated using advanced 3D modelling tools (Fussell et al, 2022; Vogt & Seufert, 2021).

Systematic reviews such as those Sharmin, Chow and King (2023) have shown that spatial teaching tools can significantly enhance students' spatial reasoning and conceptual understanding by reducing cognitive load, enabling them to interpret complex information more effectively than with traditional 2D images. Moreover, the ability to manipulate models in and signalling with annotations provides an immersive experience which influences learning outcome and cognitive load, enhancing both teaching and learning (Albus et al, 2021).

In response to these educational challenges, this study introduces a novel framework designed to comprehensively evaluate and inform the development of VR and AR tools in educational settings. As an exemplary application of this framework, we introduce 3D Whiteboard. This technological solution aims to facilitates a seamless transition between two- and three-dimensional views and enables educators to dynamically illustrate and annotate complex structures directly within the 3D model. The 3D Whiteboard exemplifies how the framework can enhance educational technologies, demonstrating its utility in improving the visualization and interaction capabilities of immersive learning environments.

Frameworks for evaluation of VR/AR Technologies in Education

Coban et al. (2022) identify multiple attempts to assess the effectiveness of immersive virtual environments in enhancing learning outcomes and refining experimental design. These efforts have sought to determine whether such environments significantly improve educational experiences and outcomes compared to traditional learning methods, focusing on a range of factors including student engagement, retention rates, and the practical application of learned knowledge in real-world scenarios (Hamilton et al 2021).

Recent meta-analyses, such as the study conducted by Coban et al. (2022), have systematically quantified the impacts of immersive virtual reality on learning outcomes. The combined data from a broad range of studies indicates that VR has a modest yet statistically significant positive effect on learning, which can be particularly beneficial in disciplines that require strong spatial abilities, such as architecture, engineering, and geometry. Coban's analysis also highlights limitations, especially in fields that demand precise surgical skills. In these areas, VR technologies still fall short of meeting the necessary learning outcomes, suggesting a need for technological enhancements to better support skill development (Coban et al., 2022).

Acknowledging both the potential and the challenges identified in these findings, this paper introduces the Integrated VR Educational Technology Assessment (IVRETA) framework, a newly proposed framework designed to comprehensively evaluate the effectiveness and adaptability of VR and AR tools across various educational settings. This framework is constructed to facilitate educational institutions and developers in navigating the complex landscape of VR and AR implementation. By addressing three critical dimensions—(a) Interaction and Usability, (b) Learning Enhancement, and (c) Authentic Pedagogy and Adaptability—IVRETA aims to not only assess the current capabilities of VR and AR applications, but also to identify areas where further technological and instructional design innovations are needed.

The *Interaction and Usability* domain within the IVRETA framework determines how effectively VR and AR technologies facilitate user engagement and interaction. This domain assesses user control and freedom within the virtual environment, ensuring that the systems are intuitive and responsive to user inputs, which is key for maintaining an engaging and fluid user experience (Dede, 2009). The usability aspect further examines the overall functionality, focusing on learnability—how swiftly new users can understand and use the tool effectively; efficiency—how well the tool supports users in achieving their educational objectives; and satisfaction—ensuring that the user experience meets or exceeds expectations. In addition, usability is enhanced by ensuring these systems are adaptable to diverse teaching methods and learning styles, allowing for seamless integration with existing educational practices.

The *Learning Enhancement* domain focuses on how immersive technologies impact and enhance the learning process. Hamilton et al. (2021) systematic review shows that immersive technologies have the potential to significantly improve learning outcomes by providing engaging, interactive, and realistic educational experiences. However, Poupard et al (2024) review note important distinctions in cognitive load effects: AR tends to optimize cognitive load, thereby facilitating learning, while VR, although enriching the learning environment with immersive experiences, can introduce higher extraneous cognitive loads that require careful management to avoid impairing learning effectiveness. This domain is thus essential for assessing the dual impact of VR and AR on learning—enhancing comprehension and retention while managing cognitive load to ensure effective and sustainable educational benefits. In this context, the adaptability of immersive technologies to different instructional goals ensures that they not only enhance learning but also align with the curriculum, supporting various pedagogical needs across disciplines (Susanto & Rachbini, 2020).

In the *Authentic Pedagogy and Adaptability* domain we critically evaluate the realism and applicability of the learning experiences provided by the immersive technology. Fabris et all (2019) discuss how immersive technologies become more effective when they closely mimic real-world scenarios, replicating genuine educational interactions. This sense of authenticity is vital, particularly in applications like surgery, where the educational impact is measured by the student's belief in the experience's realism of the activity. Moreover, adaptability plays a vital role, as pedagogical approaches must be carefully considered and tailored to fit the specific disciplinary contexts. It ensures that the technology not only mimics real-life practices but also adapts to the unique learning outcomes of each field. Moreover, the adaptability of these technologies to different educational contexts allows them to cater to specific learning outcomes and pedagogical approaches, ensuring their relevance and effectiveness across a variety of disciplines.

3D Whiteboard: Integration and Capabilities

Building on the foundations of the IVRETA framework, the 3D Whiteboard exemplifies a powerful educational tool that integrates advanced VR and AR features to enhance the learning experience. This section describes the tool's primary capabilities across the dimensions of Interaction and Usability, Learning Enhancement, and Authentic Pedagogy and Adaptability.

Figure 1. (a) Instructor drawing a cube around a 3D model. Left image shows the instructor view while using the device, and right image shows a superimposed representation of the mode and instructor. (b) In-class real time testing. Instructor in the top-left is using the headset and exploring the model, while student is observing in the main screen, while also having access in his own laptop to explore.

Interaction and Usability
Virtual Reality Integration – The tool utilises Oculus Quest headsets, allowing educators to engage directly with 3D models. This VR capability enables users to navigate around and interact with models, providing a spatial understanding necessary for subjects requiring detailed visual comprehension. The ability to rotate and

explore models in a virtual space offers a different perspective from traditional 2D learning resources. The tool is intuitive to use with minimal training, making it accessible to a wide range of users.

Interactive Annotations – Annotations are notes or labels added to the 3D models to enhance instructional clarity. On the 3D Whiteboard, these annotations can adhere to the surfaces of models, maintaining their positions relative to the model as it is manipulated, or be created anywhere in the virtual space. This feature, showed in Figure 1 (a), significantly enhances the clarity of instructional content and allows educators to provide detailed, context-specific information directly on the models.

Learning Enhancement
Real-Time Engagement and Exploration – The tool provides functionality for students to engage in real-time with the instructor and interact with 3D models from their devices. Students can either see the instructor's view or explore the models independently as show in Figure 1 (b). This dual mode of interaction allows students to understand explanations given by the tutor using the headset while also having the flexibility to examine the models on their own

Feedback and Review – The 3D Whiteboard incorporates comprehensive feedback and review mechanisms, enabling users to capture virtual photos, videos, and audio recordings of their interactions with the 3D models. These snapshots demonstrated in Figure 2, allow for later review, facilitating detailed feedback sessions and reflective learning. By recording the learning process, students and educators can revisit and analyse specific aspects of the interaction, identifying areas for improvement and reinforcing learning outcomes. This feature enhances the overall educational experience by providing tangible records of progress and understanding.

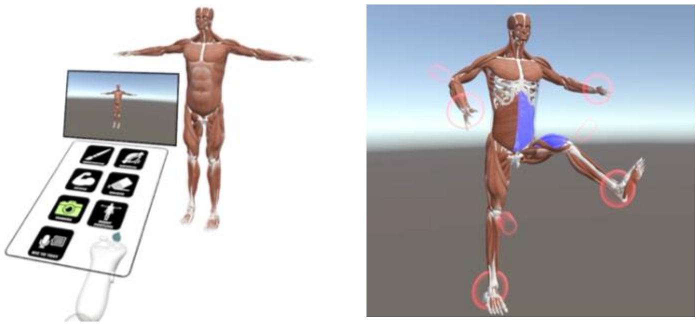

Figure 2. (left) A virtual interactive menu being used to take a photo of the model shown in the background. The virtual photo is stored for later review. (right) A virtual model used in physiotherapy testing. The highlighted red areas indicate articulations that can be moved to simulate real body movements. Specific muscles are highlighted in blue using the virtual menu, and sections of the chest area are made transparent.

Authentic Pedagogy and Adaptability
Augmented Reality Features – The AR component allows virtual models to be overlaid within the physical classroom setting, aiming to reduce the sense of isolation sometimes associated with VR technologies. By enabling participants to see their actual surroundings alongside the virtual models, this feature integrates digital and physical learning spaces, enhancing the realism and applicability of the learning experience.

Discipline-Specific Interactive Menus – The 3D Whiteboard features interactive menus tailored to the specific needs of different disciplines. This menu offers multiple capabilities, including the activation of layers, allowing users to selectively display or hide specific components of the 3D models for a more detailed and focused exploration. Figure 2 shows a virtual body model used designed for a physiotherapy class, in which articulations can be moved and muscle lawyers can be made transparent or highlighted. These discipline-specific menus enhance the learning experience by providing targeted tools and functionalities that cater to the unique requirements of various fields of study, facilitating deeper understanding and engagement.

In conclusion, applying the IVRETA framework to the 3D Whiteboard reveals significant potential to enhance educational experiences through improved interaction, usability, learning, and pedagogy. The IVRETA framework serves as a robust foundation for developers and researchers aiming to enhance and innovate educational technologies, and we are optimistic that future empirical studies will validate and refine both the framework and the tool, fostering innovation in immersive education.

References

Albus, P., Vogt, A., & Seufert, T. (2021). Signaling in virtual reality influences learning outcome and cognitive load. *Computers & Education*, *166*, 104154. https://doi.org/10.1016/j.compedu.2021.104154

Asad, M. M., Naz, A., Churi, P., & Tahanzadeh, M. M. (2021). Virtual reality as pedagogical tool to enhance experiential learning: a systematic literature review. *Education Research International*, *2021*(1), 7061623. doi:10.1155/2021/7061623

Coban, M., Bolat, Y. I., & Goksu, I. (2022). The potential of immersive virtual reality to enhance learning: A meta-analysis. *Educational Research Review*, *36*, 100452. doi:10.1016/j.edurev.2022.100452

Dede, C. (2009). Immersive interfaces for engagement and learning. *science*, *323*(5910), 66-69. doi: 10.1126/science.116731

Fabris, C. P., Rathner, J. A., Fong, A. Y., & Sevigny, C. P. (2019). Virtual reality in higher education. *International Journal of Innovation in Science and Mathematics Education*, *27*(8). doi:10.30722/IJISME.27.08.006

Fussell, S. G., & Truong, D. (2022). Using virtual reality for dynamic learning: an extended technology acceptance model. *Virtual Reality*, *26*(1), 249-267. doi:10.1007/s10055-021-00554-x

Gurses, M. E., Gonzalez-Romo, N. I., Xu, Y., Mignucci-Jiménez, G., Hanalioglu, S., Chang, J. E., ... & Preul, M. C. (2024). Interactive microsurgical anatomy education using photogrammetry 3D models and an augmented reality cube. *Journal of neurosurgery*, *1*(aop), 1-10. doi:10.3171/2023.10.JNS23516

Halabi, O. (2020). Immersive virtual reality to enforce teaching in engineering education. *Multimedia Tools and Applications*, *79*(3), 2987-3004. doi:10.1007/s11042-019-08214-8

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: a systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1-32. doi:10.1007/s40692-020-00169-2

Hanid, M. F. A., Said, M. N. H. M., & Yahaya, N. (2020). Learning strategies using augmented reality technology in education: Meta-analysis. *Universal Journal of Educational Research*, *8*(5), 51-56. doi:10.13189/ujer.2020.081908

Ioannou, M., & Ioannou, A. (2020). Technology-enhanced embodied learning. *Educational Technology & Society*, *23*(3), 81-94. doi: 10.3102/0013189X13511661

Lege, R., & Bonner, E. (2020). Virtual reality in education: The promise, progress, and challenge. *Jalt Call Journal*, *16*(3), 167-180. https://doi.org/10.29140/jaltcall.v16n3.388

Poupard, M., Larrue, F., Sauzéon, H., & Tricot, A. (2024). A systematic review of immersive technologies for education: Learning performance, cognitive load and intrinsic motivation. *British Journal of Educational Technology*. doi: 10.1111/bjet.13503

Sharmin, N., Chow, A. K., & King, S. (2023). Effect of teaching tools in spatial understanding in health science education: A systematic review. *Canadian Medical Education Journal*, *14*(4), 70-88. doi: 10.36834/cmej.74978

Susanto, R., Rachmadtullah, R., & Rachbini, W. (2020). Technological and Pedagogical models. *Journal of Ethnic and Cultural Studies*, *7*(2), 1-14. doi: 10.29333/ejecs/311

Vogt, A., Albus, P., & Seufert, T. (2021). Learning in virtual reality: Bridging the motivation gap by adding annotations. *Frontiers in Psychology*, *12*, 645032. doi: 10.3389/fpsyg.2021.645032

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