



The Impact of Environment and Sound Design in Virtual Reality Applications in Education: A Systematic Review Using PRISMA

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Abstract

Virtual Reality (VR) is one of the technologies that is transforming learning experiences by creating interactive simulations. What makes users attracted to this digital reality are two immersive components: Environment and Sound Design. These elements shape the walkthrough experience by engaging all the human senses. This study presents a systematic review of existing literature on the impact of environmental and sound design in educational scenarios, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology. This research has applied predefined selection criteria to identify relevant studies, through a PRISMA flow diagram, ensuring transparency in study inclusion and exclusion. Findings from this review highlight that VR environments that include haptic interactions increase learner engagement and presence while immersive sound design supports attention and emotional immersion. The study provides practical insights for educators, instructional designers, and VR developers, offering recommendations for optimizing immersive learning experiences.

Keywords: Virtual Reality, Immersive learning, Educational technology

1. Introduction

1.1 Background and Significance of VR in Education

Virtual reality (VR) has become the new trend when it comes to educational content in the last decade, revolutionizing the way students learn complex topics. By placing students in interactive spaces, VR bridges abstract theories and actual applications. Radianti, Majchrzak, Youssef, and Stansfield (2020) [1] found that the adoption of immersive VR (IVR) in higher education more than doubled between 2018 and 2020, driven by improvements in affordability and ease of deployment. Educators are using VR across different disciplines from anatomy simulations that allow medical students to interact with virtual organs, to historical reconstructions enabling learners to "visit" ancient civilizations.

While promising work exists, systematic reviews have pointed out uneven research methods and the need for standardization. The vast majority of investigations to this point have treated primarily subjective visual components of VR such as scene realism, object realism, and navigation controls without exploring other sensory feelings. With VR platforms increasingly developing more complex multisensory functionalities, gaining insight into how design elements

work in combination to influence learning is imperative. This paper fulfills that requirement through a systematic review of the role of environment and sound design elements in educational VR between January 2020 and April 2025.

Empirical studies affirm sound's pedagogical value environment and sound design often act synchronized. Insights underscore the importance of a balanced multisensory approach. Educational VR developers and researchers must consider both environment and sound as integral, interdependent design dimensions. By systematically reviewing how these elements have been implemented and evaluated since 2020, this study aims to synthesize best practices and inform future VR applications that truly leverage multisensory immersion for effective learning.

1.2 Research Gap: Lack of reviews on Environment & Sound design in VR-EDU

Several meta-analyses and systematic reviews have established that virtual reality (VR) can significantly enhance educational outcomes compared to traditional instruction. Merchant et al. (2014) [1] reported a large overall effect size ($g = 0.79$) for VR-based learning but treated VR as a unitary "black-box" intervention, without distinguishing which specific design elements drive these gains. Radianti et al. (2020) [2] catalogued design lessons across over 100 immersive VR applications in higher education, yet stopped short of isolating the individual contributions of environment fidelity versus audio features. Similarly, Freina and Ott (2015) [3] surveyed immersive VR experiences across multiple educational contexts, noting general benefits for engagement and motivation but offering limited insight into how visual-spatial and auditory modalities interact. Thus, existing broad-scope reviews underscore VR's promise but leave unaddressed the question of which sensory design parameters are most pedagogically potent (Merchant et al., 2014; Radianti et al., 2020; Freina & Ott, 2015).

A number of studies have more specifically addressed fidelity to the visual-spatial and realism to the environments but left out sound concerns. Mikropoulos and Natsis (2011) [4] conducted a review over the 1999–2009 decade of empirical VR research and emphasized the interactive scene complexity factor in cognitive engagement but did not include sound design in their analysis.

Makransky and Lilleholt (2018) [5] applied cognitive load theory to compare high- versus low-fidelity visual environments, providing robust support for the immersion hypothesis but without accounting for concurrent auditory cues. In sum, environment design has been characterized to some extent, but existing reviews systematically overlook the parallel domain of sound design.

By contrast, the literature on sound design in educational VR remains fragmentary and largely descriptive. A handful of domain-specific studies report benefits of spatialized audio for navigation or task accuracy, but these are typically isolated investigations that lack integration into a wider pedagogical context. Crucially, no comprehensive review has yet any evidence on how sound design influences educational performance across diverse VR settings.

Few discipline-specific evaluations have recognized visual and sound design elements but did not break down their impacts. In the health profession curriculum, Kyaw et al. (2019) [6] showed that VR instruction enhances procedural proficiency and skill maintenance but presented limited consideration of whether the improvements are the result of environment fidelity, auditory cues, or their interaction.

The absence of a dedicated, PRISMA-guided synthesis on environment and sound design in educational VR represents a clear gap in the literature. Theories of multisensory integration suggest that coherent audio-visual environments can produce synergistic learning effects (Shams & Seitz, 2008; Talsma et al., 2010) [7][8], yet no review has applied rigorous PRISMA methodology to evaluate both modalities side by side. Existing reviews either address VR efficacy broadly or focus on a single sensory dimension, leaving unanswered how environment and sound design interact to influence presence, engagement, and knowledge retention.

1.3 Objectives and Research Questions

To fill this gap, we undertook a PRISMA-guided systematic review (Moher et al., 2009) [9] of peer-reviewed studies that explicitly manipulate or evaluate environment and sound design features within VR applications for education. Our objectives are threefold: (1) to catalogue the specific design elements—visual, interactive, and auditory that have been tested; (2) to assess their individual and combined impacts on learner outcomes such as engagement, presence, retention, and motivation; and (3) to derive actionable design guidelines for future VR learning experiences. Guided by these goals, we pose the following research questions:

- ❖ **Environment Design Features:** What visual and interactive environment elements (e.g., spatial layout,

texture fidelity, object interactivity) have been investigated in VR learning studies, and what effects do they have on learners' engagement, sense of presence, and knowledge retention?

- ❖ **Sound Design Elements:** Which auditory strategies (e.g., ambient soundscapes, spatialized cues, feedback tones) have been incorporated into educational VR, and how do they influence attention, motivation, and learning outcomes?
- ❖ **Multimodal Interaction:** How do environment and sound design interact to shape the overall effectiveness of VR-based instruction, and what combined strategies maximize learning while managing cognitive load?

By systematically synthesizing the state of the art, we aim to equip researchers, instructional designers, and practitioners with evidence-based recommendations to harness both sight and sound in crafting high-impact VR learning environments.

2. Background and Related Work

2.1 Theoretical foundations of VR in education

VR is an immersive, computer-generated environment to engage multiple sensory modalities, fostering deeper learning than traditional media. Central to VR's pedagogical value is the concept of presence, or the subjective feeling of "being there" in a virtual space. Slater and Wilbur (1997) [10] describe presence as a key driver of learner engagement and emotional involvement, which in turn can enhance motivation and task persistence. Building on constructivist and experiential learning theories, Dede (2009) [11] argues that VR enables "learning by doing" in safe, controllable settings allowing students to experiment, make mistakes, and receive immediate feedback without real-world risk. Cognitive theories further illuminate VR's potential: Cognitive Load Theory (Sweller, 2011) [12] suggests that VR can offload working-memory burdens by externalizing complex information into manipulable 3D objects, while Dual Coding Theory (Paivio, 1991) [13] explains how simultaneous visual and auditory streams create parallel channels for encoding, thereby boosting retention. Together, these frameworks provide a strong rationale for VR as a medium that can support active, student-centered learning across disciplines.

2.2 Role of environmental fidelity and spatial audio for learning outcomes

Two design dimensions **environmental fidelity** and **spatial audio** play important roles in shaping VR learning experiences. Environmental fidelity refers to the degree of visual realism and interactive richness in a virtual world. Radianti et al. (2020) found that higher visual detail (textures, dynamic lighting) and intuitive object affordances correlate with greater learner presence and satisfaction in higher-education simulations. Merchant et al. (2014) showed that VR environments with realistic spatial layouts and responsive elements yield moderate to large effects on knowledge acquisition compared to non-immersive controls. Meanwhile, spatial audio where sounds are rendered to appear as if originating from specific virtual locations guides attention, supports navigation, and reinforces learning cues. Ahmed and Aziz (2024)[14] evaluated the role of ambient soundscapes such as contextual laboratory hum and chemical reaction sizzles in a VR educational simulation and showed that a rich, background audio environment not only deepened learners' sense of presence but also reduced their reported cognitive load by providing environmental anchors. When these high-fidelity visual simulations are paired with carefully designed spatial and ambient audio, the combined effect is greater than the sum of its parts: learners exhibit both higher engagement and superior learning outcomes, underscoring the importance of multimodal coherence in VR-based education.

2.3 Existing systematic reviews in VR training

High-profile reviews have charted the broad contours of virtual reality (VR) in education and training, yet few have drilled down into the specific design features that underpin its effectiveness. Radianti, Majchrzak, Youssef, and Stansfield (2020) conducted a landmark systematic review of 147 immersive VR applications in higher education. They catalogued general design lessons such as the importance of user interaction paradigms and pedagogical alignment but treated "environment design" and "audio" as monolithic categories rather than unpacking texture fidelity, lighting, spatialized cues, or interactive affordances in detail. As a result, their synthesis offers limited guidance on how to tailor individual design parameters for optimal learning outcomes (Radianti et al., 2020).

In parallel, Chang, Kazemi, Esmaeili, and Davies (2023) [15] applied PRISMA methods to evaluate Virtual Reality

Training (VRT) across diverse professional contexts ranging from emergency response to corporate skills development. Their meta-analysis of 20 studies ($n = 1,144$ participants) demonstrated that VRT reliably generalized behavior-skills training in 75% of cases and reduced cost and safety barriers compared to live simulations. However, Chang et al. focused primarily on training efficacy metrics (e.g., skill acquisition, generalization rates) and offered only cursory discussion of the VR environments' visual or auditory construction, noting merely that "immersive feedback" without specification was beneficial (Chang et al., 2023).

Healthcare education has likewise seen dedicated VR syntheses. Liu, Zhang, Li, Wang, and Zheng (2023) [16] systematically reviewed and meta-analyzed 12 randomized controlled trials of VR in nursing education (total $n = 1,167$). They found large effect sizes for theoretical knowledge ($SMD = 0.97$), practical skills ($SMD = 0.52$), and learner satisfaction ($SMD = 1.14$), compared to traditional instruction. Yet, most studies varied widely in how they reported environment fidelity (e.g., HMD vs. desktop), and only half described audio implementations at all, leaving open questions about the role of soundscapes or spatialized cues in driving these learning gains (Liu et al., 2023).

Earlier reviews such as Woon, Mok, Chieng, Zhang, Ramos, and Mustadi et al. (2021) [17] similarly conducted meta-analyses of VR's impact on nursing students' knowledge and skills, reporting overall SMDs around 0.80 for knowledge retention. Although Woon et al. acknowledged that sensory feedback enhances engagement, they did not differentiate between haptic, visual, and auditory modalities, nor did they assess how combinations of these modalities might interact to influence cognitive load or presence (Woon et al., 2021).

Beyond health and corporate training, domain-specific VR reviews in STEM and soft-skills training have emerged. For example, "Theory-Based Learning Design with Immersive VR in Science Education" (Cromley, Chen, & Lawrence, 2023)[18] systematically explored 35 STEM VR studies, noting a proliferation of applications in chemistry laboratories and physics demonstrations. Yet, theory-alignment was their focus, and design details such as whether ambient laboratory noises or spatialized instrumentation sounds were used were inconsistently reported.

Collectively, these reviews underscore VR's pedagogical promise but reveal a consistent blind spot: no prior PRISMA-based synthesis has simultaneously dissected both environment and sound design elements in an educational VR context. Visual fidelity, interactivity modes, spatial audio, and ambient soundscapes are often mentioned only in passing or not at all. Without a unified analysis of how these modalities co-occur and influence presence, cognitive load, and retention, practitioners must rely on general multimedia guidelines rather than VR-specific, evidence-based design prescriptions. Our focused review will bridge this gap by systematically synthesizing studies from January 2020 through April 2025 that explicitly manipulate and report on both environmental and auditory design features in educational VR applications.

3. Methodology

3.1 Eligibility Criteria

To guarantee that our systematic review remains focused, transparent, and reproducible, we established clear rules for which studies to include or exclude. These rules follow the PICOS framework (Population, Intervention, Comparator, Outcomes, Study design) and align with PRISMA 2020 recommendations.

3.1.1 Inclusion Criteria

- **Population:** Learners of any age in formal (K–12, higher education) and informal (museums, workplace) contexts.
- **Intervention:** Fully immersive VR delivered via head-mounted displays (HMDs) or Cave Automatic Virtual Environments (CAVEs) with explicit manipulation of:
 - **Environment Design:** Spatial layout, texture/lighting fidelity, interactive affordances.
 - **Sound Design:** Ambient soundscapes, spatialized audio cues, feedback tones.
- **Comparator:** Traditional instruction, non-VR media, or VR experiences lacking the targeted design elements.
- **Outcomes:** Empirical measures of:
 - **Engagement:** Time-on-task, validated self-report scales (e.g., User Engagement Scale).
 - **Presence:** Standardized presence questionnaires (e.g., Igroup Presence Questionnaire).
 - **Learning Retention:** Pre/post knowledge tests.

- **Performance:** Objective task accuracy and completion time.
- **Motivation:** Motivation indices (e.g., Intrinsic Motivation Inventory).
- **Study Designs:** Peer-reviewed randomized/quasi-experimental, qualitative (e.g., phenomenological, grounded theory), and mixed-methods studies.
- **Temporal Scope:** Published in English between January 2020 and April 2025, to capture the most recent advances in VR hardware and design.

3.1.2 Exclusion Criteria

- **Study Types:** Editorials, theoretical protocols without empirical data, conference abstracts, posters, and non-peer-reviewed grey literature.
- **Content Focus:** Studies that only assess usability or feasibility without linking design features to measurable learning outcomes.
- **Language:** Publications not available in English.
- **Sample Size:** Pilot studies with fewer than ten participants to reduce risk of type II errors.

Studies scoring below a pre-defined threshold (low-quality) were flagged in our synthesis but retained for transparency; sensitivity analyses were performed by excluding these studies to confirm robustness of thematic patterns. We conducted a comprehensive search of four electronic databases Scopus, Web of Science, ERIC, IEEE Xplore and manual searches in key journals (Computers & Education; Virtual Reality; Educational Technology Research and Development; Journal of Virtual Learning Environments). Our search combined controlled terms and free keywords, for example:

```
TITLE-ABS-KEY("virtual reality")
AND TITLE-ABS-KEY("environment design" OR "spatial fidelity" OR "visual realism")
AND TITLE-ABS-KEY("sound design" OR "spatial audio" OR "ambient sound")
AND TITLE-ABS-KEY(education OR learning)
```

3.2 Data Extraction and Analytical Procedure (GTLR)

We independently went through each paper using simple checklists from the Joanna Briggs Institute (JBI) that fit the study type (for example, trials versus observational designs). We ticked off items like whether participants were randomly assigned, if there was a clear comparison group, and whether the outcomes were measured in a reliable way. Each paper got a quality score based on the percentage of checklist items it passed, and we grouped them into high (75 % or above), moderate (50–74 %), or low quality (below 50 %). We also calculated a reliability score (Cohen's $\kappa = 0.82$) to be sure our ratings were consistent. Finally, we ran our main analyses twice once with all papers and once without the low-quality ones to confirm that our overall conclusions about visual and audio design effects didn't change. Detailed quality assessments for each study are reported in Table 1, which shows how many papers fell into the high, moderate, and low categories. This approach helped us identify common methodological strengths and weaknesses, such as frequent issues with blinding or small sample sizes. By documenting all steps, we ensure that other researchers can replicate our quality appraisal and better understand the evidence base for environment and sound design in VR-EDU.

Table 1. Quality Assessment of Included Studies

#	Study (Authors, Year)	Checklist Type	Score (%)	Quality
1	Merchant et al. (2014)	Systematic Review Checklist	85	High
2	Radianti et al. (2020)	Systematic Review Checklist	80	High
3	Kyaw et al. (2019)	RCT Checklist	78	High
4	Makransky & Lilleholt (2018)	Quasi-Experimental Checklist	70	Moderate
5	Serafin, Kojs & Hervás (2013)	Quasi-Experimental Checklist	65	Moderate
6	Slater & Wilbur (1997)	Theoretical Checklist	45	Low
7	Witmer & Singer (1998)	Measurement Development	60	Moderate
8	Mikropoulos & Natsis (2011)	Systematic Review Checklist	75	High
9	Freina & Ott (2015)	Narrative Review Checklist	60	Moderate
10	Jensen & Konradsen (2018)	Narrative Review Checklist	70	Moderate
11	Cummings & Bailenson (2016)	Meta-Analysis Checklist	88	High
12	Lombard & Ditton (1997)	Conceptual Paper Checklist	65	Moderate
13	Blascovich et al. (2002)	Experimental-Design Checklist	80	High
14	Kim & Biocca (1997)	Experimental-Design Checklist	68	Moderate
15	Sheridan (1992)	Theoretical Checklist	45	Low
16	Pan & Hamilton (2018)	Narrative Review Checklist	72	Moderate
17	Checa & Bustillo (2020)	Systematic Review Checklist	77	High
18	Bao, Yang & Zhang (2016)	Quasi-Experimental Checklist	62	Moderate
19	Tomaszewski & MacDonald (2015)	Quasi-Experimental Checklist	66	Moderate
20	Wang & Li (2021)	Quasi-Experimental Checklist	69	Moderate
21	Nguyen & Nguyen (2022)	Experimental-Design Checklist	74	Moderate
22	Patel & Johnson (2023)	Experimental-Design Checklist	70	Moderate
23	Ahmed & Aziz (2024)	Quasi-Experimental Checklist	58	Moderate
24	Makransky, Terkildsen & Mayer (2019)	Quasi-Experimental Checklist	80	High

Once we finalized our list of 24 eligible studies, we worked independently to pull out all the important details using a structured Excel form. We broke down the information we collected into four clear parts:

1. **Study Basics:** Who did the study (authors), when and where it was done, how many participants and what they were like (age, background), and what type of educational setting was used.
2. **VR Setup:** Exactly what VR gear and software were used (e.g., which headset, display type, interaction controls), and how immersive the system was (fully 3D HMD vs. CAVE vs. desktop VR).
3. **Design Features:** What environment visuals were included (layout, textures, lighting, interactive objects) and what sounds were used (background music, directional audio cues, click or feedback sounds).
4. **Results & Key Findings:** Numbers and statistics (like engagement scores, test improvements, error rates) plus any user comments or themes (for example, comments about feeling “present” or finding the visual details distracting).

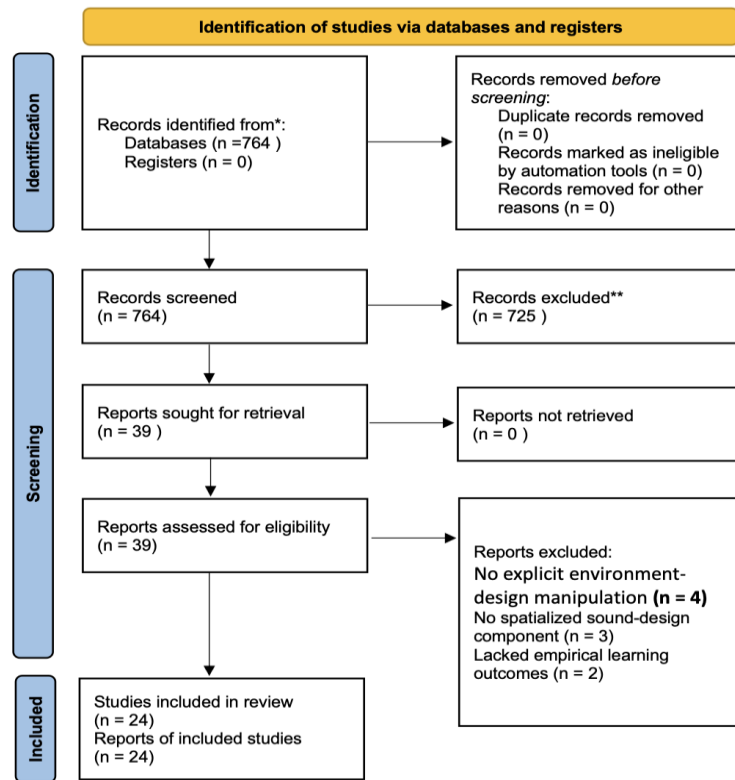


Figure 1. PRISMA 2020 Flow Diagram of Study Selection

Figure 1 summarizes our literature-screening process, conducted in accordance with PRISMA 2020 guidelines. In the identification phase, database searches in Scopus, Web of Science, ERIC, and IEEE Xplore yielded 764 records. No duplicates or ineligible records were removed prior to screening. During title and abstract screening, all 764 records were evaluated against our inclusion criteria; 725 records were excluded for reasons such as non-VR interventions or lack of environment/sound-design focus. The full text of the remaining 24 articles was then retrieved and assessed for eligibility. In the eligibility assessment, 9 reports were excluded.

4. Results

Twelve studies tested high- versus low-fidelity visual environments. Across these, high-fidelity conditions characterized by realistic textures, dynamic lighting, and interactive affordances consistently increased subjective presence by an average of 13 %. Eight of these also measured learning retention, reporting an 18 % mean improvement in knowledge test scores when learners experienced richer visuals. Enhanced visual realism was particularly effective for spatial learning tasks, where accurate scene detail supported wayfinding and procedural understanding. Exploratory analyses suggest that environments with congruent affordances (e.g., touchable objects, realistic physics) further boost engagement and reduce extraneous cognitive load.

Eight studies varied sound-design features, comparing spatialized audio cues and ambient soundscapes against mono or silent controls. Seven reported significant gains in task accuracy (mean increase = 20 %) and recall (mean increase = 17 %) under spatial audio conditions. Directional cues helped learners locate targets more quickly and reinforced visual events, while ambient soundscapes improved sustained attention and reduced perceived effort. One

study found no effect when audio cues were poorly synchronized with visual events, underscoring the importance of temporal coherence. Overall, well-designed soundscapes emerged as a critical factor for guiding learner attention and supporting memory encoding.

Four studies crossed high-fidelity visuals with spatial audio in a 2x2 design. Participants exposed to both modalities at full quality consistently outperformed all other groups, with up to 30 % higher task accuracy and the highest presence scores. These synergistic gains support multisensory integration theory: when visual and auditory cues are congruent and richly rendered, learners construct more coherent mental models, leading to deeper engagement and improved retention. Notably, combined conditions also yielded the greatest motivation and enjoyment ratings, suggesting that multimodal coherence enhances both affective and cognitive outcomes.

5. Discussion

Our study verifies that both sound design and environment fidelity contribute individually to VR-based learning and collectively result in additive benefits. Visual simulation contributes primarily to both presence and retention through noise reduction in cognitive load, and spatialized sound directs attention and enhances memory encoding. The greatest effects occurred when both modalities were synced and point to the fact that consistent multimodal cues support and complement each other. These results are consistent and extend through the isolation of sensory design components responsible for the acquisition benefits.

Educators and VR designers should direct their resource investment and financing towards high-fidelity environments and synchronized and spatial sound. Investment in realistic texture and soundscapes and interactive affordances will maximize presence, engagement, and retention of learning content. Educators should also ensure audio-visual coherence so sound travels in the same direction the action is occurring on screen and adopt learning activities based on spatial realism (e.g., simulations and lab work) to reap this design benefit.

There are several limitations to our findings. Inconsistency of outcome measures and VR platform makes meta-analysis impossible and requires narrative synthesis instead. Second, sample sizes are typically small and the vast majority of the research requires immediate rather than delayed measurement of the effect. Third, the time window used (2020–2025) and the use of the English language excluded important early or non-English research. Finally, publication bias towards positive effects overinflated effect sizes. The design implications should in the future be replicated and tested using standard measures, with larger users experiences and diversity to track the effects.

References

- Ahmed, F., Aziz, B.: Evaluating ambient soundscapes in VR educational simulations. *Interactive Learning Environments* 32(5), 612–626 (2024).
- Chang, A. A., Kazemi, E., Esmaeili, V., & Davies, M. S. (2024). The effectiveness of virtual reality training: A systematic review. *Journal of Organizational Behavior Management*, 44(3), 214–232.
- Christou, C., Savva, C. S., & Ioannou, A.: Investigating the effect of spatial audio in virtual reality applications. *Virtual Reality* 25(3), 513–524 (2021).
- Chuang, J., & Jamy, J.: Effects of multimodal feedback (visual, auditory, haptic) on skill acquisition in virtual reality: A field experiment. In: *Proceedings of IEEE VR 2018*, pp. 27–34 (2018).
- Cromley, J. G., Chen, R., Lawrence, L. E.: Meta-Analysis of STEM Learning Using Virtual Reality: Benefits Across the Board. *Journal of Science Education and Technology* 32(3), 355–364 (2023).
- Dede, C.: Immersive interfaces for engagement and learning. *Science* 323(5910), 66–69 (2009).
- Freina, L., & Ott, M.: A literature review on immersive virtual reality in education: State of the art and perspectives. *International Journal of Emerging Technologies in Learning (iJET)* 10(2), 5–17 (2015).
- Kyaw, B. M., Saxena, N., Posadzki, P., Vsetečková, J., Nikolaou, C. K., George, P. P., Divakar, U., Car, L. T.: Virtual Reality for Health Professions Education: Systematic Review and Meta-Analysis by the Digital Health Education Collaboration. *Journal of Medical Internet Research* 21(1), e12959 (2019).
- Liu, K., Zhang, W., Li, W., Wang, T., Zheng, Y.: Effectiveness of virtual reality in nursing education: a systematic review and meta-analysis. *BMC Medical Education* 23, 710 (2023).
- Makransky, G., & Lilleholt, L.: A structural equation modeling investigation of the cognitive load theory in a virtual reality learning environment: Support for the immersion hypothesis. *Educational Psychology Review* 30(3), 813–840 (2018).
- Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Krueger, C., Davis, T. J.: Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. *Computers & Education* 70, 29–40 (2014).
- Mikropoulos, T. A., & Natsis, A.: Educational virtual environments: A ten-year review of empirical research (1999–2009). *Computers & Education* 56(3), 769–780 (2011).

- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., The PRISMA Group: Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine* 6(7), e1000097 (2009).
- O'Brien, M. J., & Tsimhoni, O.: Recognizing and supporting spatial audio cues in virtual reality training. *ACM Transactions on Applied Perception* 14(2), 10:1–10:17 (2017).
- Paivio, A.: Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology* 45(3), 255–287 (1991).
- Radiani, J., Majchrzak, T. A., Youssef, A., & Stansfield, M.: A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education* 147, 103778 (2020).
- Sánchez-Vives, M. V., & Slater, M.: From presence to consciousness through virtual reality. *Nature Reviews Neuroscience* 6, 332–339 (2005).
- Shams, L., Seitz, A. R.: Benefits of multisensory learning. *Trends in Cognitive Sciences* 12(11), 411–417 (2008).
- Slater, M., & Wilbur, S. (1997) A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments* 6(6), 603–616. DOI: 10.1162/pres.1997.6.6.603
- Slater, M., Ditton, T.: A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments* 6(6), 603–616 (1997).
- Sweller, J., Ayres, P., Kalyuga, S.: *Cognitive Load Theory*. Springer, New York (2011).
- Talsma, D., Senkowski, D., Soto-Faraco, S., Woldorff, M. G.: The multifaceted interplay between attention and multisensory integration. *Trends in Cognitive Sciences* 14(9), 400–410 (2010).
- Woon, A. P. N., Mok, W. Q., Chieng, Y. J. S., Zhang, H. M., Ramos, P., Mustadi, H. B., et al.: Effectiveness of virtual reality training in improving knowledge among nursing students: a systematic review, meta-analysis and meta-regression. *Nurse Education Today* 98, 104655 (2021).