Journal of Learning and Teaching in Digital Age, 2026, 11(3), 159-177
https://dergipark.org.tr/en/pub/joltida
ISSN: 2458-8350 (online)

Research Paper

Development of Design Guidelines for Virtual Learning Environments in Online VR Platforms

Minel Kurtuluş[a*], Çiğdem Tekin

[a](ORCID ID: 0000-0003-4623-0613), Istanbul Gelisim University, Faculty of Fine Arts, Department of Interior Architecture, Türkiye, mikurtulus@gelisim.edu.tr
[b](ORCID ID: 0000-0002-1777-8594), Mimar Sinan Güzel Sanatlar University, Faculty of Architecture, Department of Architecture, Türkiye, cigdem.tekin@msgsu.edu.tr

[*]Corresponding author

ARTICLE INFO
Received: 16 October 2025
Revised: 03 March 2026
Accepted: 12 March 2026

Keywords:
Online Learning, Virtual Learning Space, Virtual Learning Environment, Design Criterion, Virtual Reality, Virtual Learning Space Design

doi: 10.53850/joltida.1804901

ABSTRACT
Background: The transition from physical classrooms to virtual environments requires rethinking learning spaces in both spatial and pedagogical terms. This shift involves not only a change in setting but also a reconfiguration of learning experiences and habits. Despite shared goals of effective learning, physical and virtual classrooms differ significantly in qualitative aspects. The absence of legal regulations and the dominance of non-architect professionals in designing virtual environments highlight a major gap in achieving standardized and high-quality educational spaces.
Objectives: This study aims to develop a comprehensive design guide for virtual learning environments within online virtual reality (VR) platforms, with the objectives of enhancing e-learning quality, fostering interactive educational experiences, and establishing criteria for how virtual environments should be designed to support effective learning.
Methodology: Four virtual reality (VR) platforms—Mozilla Hubs, Engage, Meta Horizon, and MeetinVR—were selected as experimental settings. On each platform, participants attended as listeners a 30 -minute theoretical lecture on architecture, material use, and the Industrial Revolution, ensuring consistent educational content across all environments. The study involved 20 participants—10 interior architecture students and 10 faculty members from the Istanbul Gelişim University Interior Architecture Department. A two-hour orientation session was conducted to familiarize participants with the VR headsets and controllers before the experiment. Afterwards, each participant completed a total of 120 minutes of immersive virtual education. Following the sessions, participants filled out structured questionnaires and open-ended feedback forms assessing material, texture, lighting, form, color, size, and scale. The collected data were analyzed using IBM SPSS and MAXQDA to evaluate spatial perception and user experience.
Findings: Results show that design elements of VR-based learning spaces directly affect user perception and satisfaction. Material, lighting, and scale notably enhance realism and educational effectiveness. The study provides practical recommendations for user-centered design in VR-supported learning environments, contributing to the development of virtual educational spaces in interior architecture education.

INTRODUCTION

Throughout history, educational spaces have undergone a continuous transformation in parallel with pedagogical approaches and technological developments. This transformation—from the traditional classrooms of the 19th century to today's digital, interactive, and multidimensional virtual learning environments—has accelerated notably in the 21st century with the incorporation of virtual reality (VR), augmented reality (AR), and metaverse technologies into educational practices (Dede, 2009; Johnson et al., 2016). Through these emerging technologies, learners have transitioned from passive recipients of information to active agents in the learning process, fostering a shift toward more personalized, accessible, and experience-driven modes of education (Merchant et al., 2014).

The emergence of virtual learning environments has influenced not only formal educational contexts but has also fostered the adoption of mobile and flexible learning models in informal settings such as communities, homes, and workplaces. As a result, education has evolved beyond spatial boundaries, transforming into a digitized and dynamic learning ecosystem. Among these innovations, the blended (hybrid) learning approach integrates the strengths of both online and face-to-face instruction, allowing adaptation to students' individual learning styles, rhythms, and preferences (Webster, 2016).

With the proliferation of online platforms since the 1990s, course materials have become digital; interactive learning tools and synchronous/asynchronous education models have become widespread; educational costs have decreased, and access opportunities have expanded (Anderson, 2008; Bates, 2005). After 2010, with the widespread adoption of VR and AR technologies, learning environments have become even more digitalized, abstract concepts have been concretized, and experience-based learning opportunities have increased (Dede, 2009; Merchant et al., 2014). Metaverse technologies indicate a new paradigm in education by enabling multilayered, realistic, and personalized digital learning worlds.

The COVID-19 pandemic has highlighted the critical role of digital transformation in sustaining the continuity and quality of education. It has strengthened the reliance on online learning systems, emphasizing the necessity for educational institutions to accelerate their transition toward digitally integrated infrastructures (Hodges et al., 2020). In this process, the quality, accessibility, and sustainability of virtual education platforms have become critical. While developed countries (USA, European countries, South Korea, Singapore, etc.) have made significant investments in online education technologies (Allen, 2011; Laurillard, 2012; Lim, 2012), countries like Turkey have faced various inequalities due to limited access and infrastructure deficiencies (Karal, 2011).

In this transformation process, the discipline of architecture plays a critical role in redesigning learning environments in accordance with user needs. Ensuring physical and psychosocial comfort, spatial efficiency, flexibility, and integration with digital learning environments are among the primary priorities of today's architectural design processes (Galan, 2017). Architecture is regarded not only as a process of building production but also as a design tool that shapes user experiences, supports learning processes, and enhances spatial functionality. In this regard, architects must analyze user behaviors, pedagogical approaches, and technological needs to design innovative and multifunctional educational environments.

With the growing prevalence of virtual and hybrid learning models, architects are increasingly expected to develop design solutions that address spatial perception and interaction not only in physical spaces but also within digital environments. However, the absence of standardized criteria and design principles for virtual classrooms often leads to inconsistencies in user experiences, where essential elements such as ergonomics, interaction quality, and integration with digital materials may be neglected. This deficiency highlights the necessity for a design framework rooted in architectural principles and informed by interdisciplinary collaboration, addressing both the physical and perceptual aspects of virtual learning environments. Through partnerships between architects and specialists in educational technology and pedagogy, it becomes possible to develop inclusive, accessible, and pedagogically supportive virtual spaces. Within this scope, the convergence of architecture and educational technologies defines a growing domain of interaction and influence. Consequently, the present study examines virtual learning environments from the perspectives of spatial perception and user experience, with the objective of formulating architecture-based criteria for the design of effective virtual classrooms.

METHOD

Material

In this study, four different VR-supported platforms were selected to examine the physical environmental components of virtual learning environments: Mozilla Hubs, Engage, Meta Horizon, and MeetinVR. These platforms are widely preferred at the international level for educational purposes and offer diverse design features, making them suitable for comparative analysis.

Mozilla Hubs enables users to easily create virtual spaces through its open-source and accessible structure; Engage stands out with its interactive content support tailored for professional education and business meetings. Meta Horizon draws attention with its social interaction-oriented structure and user-generated content, while MeetinVR offers a user-friendly interface optimized specifically for meeting and educational scenarios.

The selection of these platforms was informed by several criteria, including a review of current literature, positive user feedback regarding experiential quality, widespread adoption by educational institutions, and the distinct physical environmental characteristics each platform provides. These platforms were utilized as research environments to assess the multidimensional nature of VR learning spaces and to analyze user perceptions related to physical environmental components.

Method

This research was structured around an eight-phase methodological framework designed to determine design parameters for virtual reality (VR)-based educational environments and to formulate a comprehensive set of design guidelines. The methodological approach follows a mixed-method strategy, integrating qualitative insights with quantitative data collection to ensure a multidimensional understanding of the subject.

Participant Selection: The participant group comprised ten undergraduate students and ten academic staff members from the Department of Interior Architecture at Istanbul Gelisim University, each possessing considerable experience with online learning acquired during the COVID-19 pandemic period. Participants were selected through purposive sampling not only based on their academic level but also according to their prior engagement with virtual learning environments. In addition to their experience in remote teaching and learning, the faculty members were specifically chosen for their research or pedagogical involvement in the field of VR-based education. This selection ensured that all participants possessed sufficient familiarity with both the opportunities and the challenges associated with VR-supported educational settings, enabling a more informed evaluation of virtual learning environments.

Orientation Training: Participants received a brief orientation session on the basic use of VR headsets and controllers. This phase introduced the Oculus Meta Quest 2 device in particular, and participants were guided through a process of adaptation to the virtual environment.

Course Content and Time Planning: As part of the research, a 30-minute theoretical course was developed within a virtual reality (VR) environment and optimized to minimize cognitive load. The course content focused on conceptual subjects, including the Industrial Revolution and the interplay between technology and architecture. Accordingly, each participant engaged in a total of 120 minutes of VR-based class sessions as a listener, thereby experiencing an immersive and interactive virtual classroom setting.

Technical Infrastructure Preparation: The course environment was equipped with Oculus Meta Quest 2 headsets, and all necessary technical integrations and software updates were completed. Preparatory procedures were implemented in alignment with the compatibility requirements of the selected virtual reality (VR) platforms.. Each participant created a personal Meta account and attended the courses using their individual memberships.

Implementation of VR Learning Environment Experiences: Participants experienced the designated course content within the virtual reality environment. During this process, data collection on the perception of physical environmental components was initiated.

Survey Development Process:

- The survey development process consisted of four main stages:
- Analysis of the 2015 Minimum Design Standards Guide for Educational Facilities
- Examination of exemplary educational spaces submitted to the IPMA 2018 competition
- Collection of expert opinions from designers specialized in both virtual and physical space design
- Qualitative evaluations obtained from academics working in the relevant literature
- Based on the findings derived from this multi-layered dataset, the survey questions were structured and finalized.

Survey Implementation: The finalized survey was administered to both student and academic participants following the VR course experience. In addition to closed-ended items, the survey included open-ended sections for qualitative feedback.

Survey Data Analysis: The collected data were processed using the SPSS statistical software package. Descriptive statistics were computed, and inferential analyses—including independent samples t-tests and analyses of variance (ANOVA)—were conducted to examine group differences. Significant differences were identified based on participant types and their levels of experience.

Educational Platforms Supported by Virtual Reality (VR)

Mozilla Hubs: Developed by the Mozilla Foundation, Mozilla Hubs is an open-source, web-based virtual reality platform. Launched in 2018, the platform enables users to access virtual environments directly through a web browser without the need to install any software. Hubs offers an interactive VR experience through features such as avatar creation, virtual room design, media sharing, and real-time voice and text communication.

In this study, a virtual classroom titled “ROOM 2” within the Mozilla Hubs platform was selected using a random sampling method and accessed via Oculus Meta Quest 2 headsets. Participants joined the session independently by using the same room code. Orientation and navigation within the VR environment were carried out using handheld controllers.

The selected virtual classroom includes natural and artificial lighting elements, 30 student desks, a teacher's desk, bulletin boards, and world maps. The course content was designed as a 30-minute theoretical session on material science, and the physical environmental components of the virtual space were evaluated from the perspective of user perception. In this context, Mozilla Hubs served as an effective tool in the experimental phase of the study due to its realistic and customizable virtual learning environment (Kurtuluş, 2024).

Figure 1. Images from the Demo Lesson Environment in Hubs Mozilla (Kurtuluş, 2024)

MeetinVR: Developed in 2018 by the Denmark-based company MeetinVR, MeetinVR is a virtual reality-supported, interaction-oriented platform designed for education and meetings. Supporting remote learning and collaboration processes, this platform offers users real-time communication and shared workspaces through three-dimensional avatars. Accessible via web browsers and featuring virtual environments tailored to various user scenarios, MeetinVR provides interactive solutions particularly in areas such as project management, education, and idea sharing.

Within the scope of this study, the platform's virtual classroom titled "Auditorium" was selected through a random sampling method. Participants accessed the space via Meta membership and joined the 30-minute theoretical material class using Oculus Meta Quest 2 headsets. User movements were navigated using VR controllers.

The virtual classroom environment features a pentagonal layout with elevation differences and is illuminated by natural light entering through a large dome-shaped skylight. The seating arrangement accommodates 32 participants with navy-blue fabric and metallic textures. A podium reserved for the instructor is situated at a higher elevation, accompanied by a large interactive board framed between massive wooden panels. The prominent use of natural materials, variations in spatial scale, and overall spatial organization within the interior directly influenced the user experience (Kurtuluş, 2024).

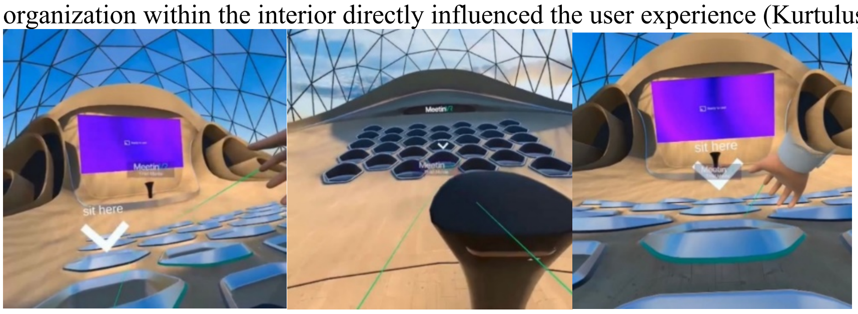

Figure 2. Images from the Demo Lesson Environment in MeetinVR (Kurtuluş, 2024)

Engage: Engage is a virtual reality-supported education and communication platform developed in 2017 by ENGAGE XR, a company based in Ireland (formerly known as Immersive VR Education). The platform enables real-time interaction through personalized avatars and allows users to meet and collaborate in three-dimensional virtual environments. Engage facilitates the creation of virtual classrooms, particularly for educational purposes, and supports the sharing of these spaces through meeting codes, thereby eliminating geographical barriers and fostering interactive learning environments.

Within the scope of this study, a virtual classroom titled "Lecture Room," located in the "Education Plaza" section of the Engage platform, was selected using a random sampling method and experienced through Oculus Meta Quest 2 headsets. Participants attended a 30-minute theoretical material course in the same environment using individual VR devices. Movement within the environment was controlled using joystick-based hand controllers.

The virtual classroom is equipped with wooden seating for 240 people, three staircases, an instructor's podium, a teacher's desk, two chalkboards, and a projection screen supported by a curtain. The space is illuminated solely by artificial lighting, with a dominant use of wooden textures and dark green tones. The amphitheater-style classroom also features two exit doors located at the upper levels (Kurtuluş, 2024).

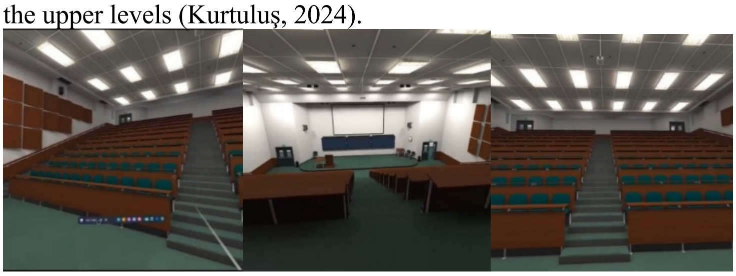

Figure 3. Images from the Demo Lesson Environment in Engage (Kurtuluş, 2024)

Meta Horizon: Meta Horizon Workrooms is a virtual reality-supported platform developed by Meta (formerly Facebook) in 2021 for the purposes of remote education and meetings. The platform offers users advanced collaboration tools such as customizable avatars for virtual interaction, document sharing, whiteboard usage, note-taking, voice communication, and a virtual tablet. Due to these features, it is widely used in both educational and corporate contexts.

Within the scope of this study, a virtual classroom titled "Work Room" was randomly selected from the "Rooms" section of the platform and experienced using Oculus Meta Quest 2 headsets. The classroom selection and desk height were adjusted via joystick controllers based on individual user dimensions, and users were automatically teleported into the environment. Participants engaged in real-time interaction during a 30-minute theoretical VR course conducted in the same virtual space.

The virtual classroom features a seating arrangement for 16 individuals divided into four separate groups. Artificial lighting is provided by ceiling light strips and pendant fixtures, while natural lighting enters through a glass ceiling and wall-mounted windows. The interior design includes wooden finishes, dark gray tones, and lilac-colored accessories. The instructional area is equipped with a wooden podium, a microphone, and a virtual tablet (Kurtuluş, 2024).

Figure 4. Images from the Demo Lesson Environment in Meta Horizon (Kurtuluş, 2024)

Beyond their general descriptions, the selected VR platforms were comparatively analyzed in terms of spatial configuration, scale, circulation structure, lighting strategy, material expression, and spatial hierarchy. This analysis aimed to examine how architectural principles are simulated and reinterpreted within immersive digital environments.

Mozilla Hubs reflects a conventional linear classroom typology, organized around a clear frontal teaching axis and repetitive seating layout. Its moderate scale and balanced use of artificial and simulated natural lighting create a structured and accessible learning environment emphasizing clarity over spatial complexity.

MeetinVR presents a more articulated spatial geometry. The pentagonal layout and sectional level differences enhance volumetric perception, while the dome-shaped skylight strengthens vertical emphasis. The use of wood textures and material contrasts contributes to realism and reinforces spatial hierarchy between instructor and audience.

Engage adopts a large-scale amphitheatrical model with tiered seating and strong frontal orientation. Its monumental scale and artificial lighting dominance create a formal academic atmosphere, though the large capacity reduces spatial intimacy and alters interaction dynamics.

Meta Horizon Workrooms introduces a collaborative layout with smaller seating clusters and adjustable ergonomic features. Its hybrid spatial logic combines meeting-room functionality with educational use, supported by controlled natural light simulation and a restrained material palette.

Comparatively, the platforms represent four spatial typologies within VR education: traditional linear classroom, volumetrically articulated semi-formal classroom, institutional amphitheater, and collaborative modular workspace. These differences enabled the evaluation of how spatial scale, hierarchy, and material simulation shape user perception and learning experience (Kurtuluş & Tekin, 2026).

Design and Construction of the Research Questionnaire

Construction and Refinement of the Survey Items

The survey instrument developed for this study was specifically designed to assess VR-supported educational environments with respect to their physical and environmental components, serving as an original measurement framework. The formulation of the survey questions followed a data-driven, multi-phase process that integrated both qualitative and quantitative perspectives. This process involved an extensive review of the existing literature, examination of relevant standards, analysis of exemplary case studies, and iterative consultations with subject-matter experts to ensure content validity and conceptual rigor..

Initially, the nationally referenced 2015 Minimum Design Standards for Educational Facilities was examined, with particular emphasis on physical environmental components such as lighting levels, noise control, ergonomic layout, material usage, and user safety. Accordingly, items such as “Did the lighting level in the space provide visual comfort?” or “Did the arrangement of the furniture support spatial circulation?" were formulated based on these standards. These questions aimed to assess participants' experiences related to visual, auditory, and spatial perceptions.

Secondly, award-winning projects from the internationally recognized IPMA 2018 Educational Space Design Competition were analyzed. These projects highlighted a user-centered design approach emphasizing flexibility, interior furnishings, technological tool utilization, acoustic regulation, and learning-interaction relationships. Consequently, the questionnaire included items such as *"Was adequate space provided to ensure users' freedom of movement within the VR environment?"* and *"Did the interactive technological tools effectively support the course content?"* These questions were specifically formulated to assess the level of interactivity and functional adequacy of virtual learning environments, ensuring that user engagement and pedagogical alignment were systematically evaluated.

The structural framework of the survey was systematically organized to evaluate the VR-supported educational process across three key phases: the pre-class phase (preparation stage), the in-class phase, and the post-class phase, each designed to capture distinct aspects of the learner's interaction and engagement within the virtual environment. Each phase was subdivided into subdimensions reflecting different user experiences. The pre-class phase included factors related to technical preparation and usability such as VR headset activation, boundary definition within the space, controller usage, external environmental conditions, and ergonomic experience of the device. The in-class phase measured user experience through spatial elements such as perception of material, color, and texture, lighting comfort, ergonomic and functional layout, acoustic quality, and flexibility. The post-class phase focused on holistic effects of the learning process including social communication, feedback, and performance evaluation. For example, questions included: "Did the device quickly and smoothly detect its position when you put on the VR headset?" for the pre-class phase; "Did the acoustics of the space positively affect content perception and your attention?" for the in-class phase; and "Do you feel you were able to express yourself adequately after the virtual lesson?" for the post-class phase.

Most of the items were formatted using a five-point Likert scale (ranging from *Strongly Disagree* to *Strongly Agree*) and were subsequently analyzed through statistical techniques, including the independent samples *t*-test and one-way analysis of variance (ANOVA), to identify significant differences across participant groups during the evaluation phase.

To ensure the content validity and contextual relevance of the survey items, a multi-layered expert consultation process was conducted. A total of nine professionals from six distinct disciplines participated in this process. The expert group consisted of two game artists, one art director, one game designer, two environmental designers, one industrial designer, one VR space designer, and two academics specializing in architecture and interior architecture. Both academics are faculty members in the Department of Interior Architecture at Mimar Sinan Fine Arts University, holding the titles of Associate Professor (Doç. Dr.) and Professor (Prof. Dr.), respectively. Experts were identified through professional networking platforms such as LinkedIn and were invited based on their proven experience in virtual environment design, digital interaction, and VR-based educational projects.

The consultation process was structured into three stages:

Stage 1 – Exploratory Interviews: Individual open-ended interviews were conducted with all nine experts to gather general insights regarding the visual, ergonomic, and interactional aspects of virtual educational environments.

Stage 2 – Draft Evaluation: The preliminary version of the questionnaire was shared with the same group of experts through a series of online meetings, during which comprehensive feedback was obtained regarding the clarity of the items, construct validity, and the overall suitability of the measurement scale.

Stage 3 – Revision and Academic Validation: The revised version was reviewed by three academics—two interior architects from Mimar Sinan Fine Arts University and one educational technology specialist—to ensure conceptual precision and linguistic coherence.

Following expert feedback, several items were refined for clarity, overlapping expressions were consolidated, and redundant questions were removed, resulting in a more coherent and functionally robust measurement tool. The multidisciplinary composition of the expert group ensured that the final version of the questionnaire integrated both practical design insights from digital environment specialists and pedagogical consistency grounded in academic expertise.Qualitative findings from experts revealed that decision-making roles such as "product manager," "art director," "game designer," and "game artist" are determinant in virtual space design processes. Additionally, spatial decisions were found to vary according to parameters such as game genre, target user profile, and usage duration; components such as lighting, materials, texture, and scale were shaped through project-specific guidelines and technical collaborations. The importance of interdisciplinary collaborations (including architecture, interior design, industrial design, and game design) in virtual space design was also emphasized. On the other hand, challenges such as documentation deficiencies, visual language consistency, color selection, and representation of abstract spaces were frequently encountered in virtual educational environments. These findings particularly highlight the necessity to develop a strong visual language that enhances user experience and supports the learning process.

As a result of all these processes, the finalized survey form emerged as a multidimensional, original, and valid assessment tool grounded in theoretical literature and tested through practitioner experience. This scale facilitates the assessment of the physical environmental adequacy of VR-supported educational settings from the users' perspective, thereby making a substantial contribution to the existing body of literature and functioning as a scientific tool that informs the design and implementation of VR applications in higher education contexts.

Survey Scales and Their Justification

The survey instrument was structured to comprehensively assess user experiences related to the design of VR-supported virtual learning environments. The scales of the survey correspond to the three fundamental phases of the lesson: pre-class, in-class, and post-class. Each phase includes distinct subdimensions reflecting users' varying spatial needs, perceptions, and experiences; differences in the number of items per scale reflect the relative importance of each criterion on the overall user experience.

Scales Related to the Pre-Class Phase

The scales addressing the pre-class phase focus on users' experiences during the entry and preparation processes within the VR environment and are organized into six subscales. These include headset activation, VR boundary definition, interface encounter, controller usage, interaction limits and access times, and external environmental conditions. Within these domains, aspects such as user comfort, safety, ease of interaction, and visual/ambient effects were evaluated. Particular emphasis was placed on users' initial interactions with the VR headset, the ergonomic characteristics of control devices, the atmospheric qualities of the virtual classroom, and the extent to which access procedures influenced users' readiness to engage with the lesson.

Scales Related to the In-Class Phase

The in-class phase section of the survey concentrates on the active learning process occurring within the virtual education setting and investigates user experiences across sixteen subscales. These criteria encompass interaction, spatial adequacy, color and interior finishes, lighting, flexibility, furniture usage, spatial form, ergonomics, acoustic arrangements, and overall user satisfaction. The survey items aim to measure how components such as learning motivation, content perception, user comfort, customizability, spatial awareness, and communication effectiveness influence learning efficiency. Particular emphasis was placed on factors directly influencing the learning process, such as the design of furniture, the harmony of form and scale, and the configuration of acoustic arrangements.

Scales Related to the Post-Class Phase

The post-class phase scales seek to analyze users' experiences following the completion of the learning process. Items in this section address social interaction needs, sense of personal space, orientation and exit strategies, and feedback on interaction duration. This evaluation focuses on user satisfaction after VR-supported lessons, quality of spatial orientation, and opportunities for social engagement within the virtual context. Through this multidimensional assessment across all phases, systematic data is gathered to inform evidence-based design recommendations.

Determination of Sample Size

The sample size (n) was calculated using the formula by Arlı and Nazik, 2001 (Gay, 1987; Arlı & Nazik, 2001, s. 77);
$n = (N * Z^2 * p * (1 - p)) / ((N - 1) *E^2 + Z^2 *p *(1 – p)$
N: Population size (127: Total number of Interior Architecture students and faculty,
Z: Confidence interval score (1.96 for a 95% confidence level)members at Istanbul Gelişim University), p: Expected proportion (0.5),
E: Margin of error (0.05)

Substituting the values, the sample size was found to be approximately 96. In descriptive research, a minimum of 10% and in small populations, 20% of the population is generally sampled. Based on this, a sample size between 10 and 20 participants was deemed appropriate (Gay, 1987; Arlı & Nazik, 2001, s. 77). Using 20% as the upper limit, the final sample size was set at 20 participants.

Statistical Analyses

The survey study was conducted with 10 students and 10 academicians who had experienced VR learning environments. The questionnaire, distributed digitally through Google Forms, was analyzed using IBM SPSS software by applying frequency analysis, independent samples t-test, analysis of variance (ANOVA), and correlation analysis techniques. Based on the results, a set of design criteria for virtual learning environments was formulated.

The analyses were organized under the headings of pre-class, in-class, post-class phases, and general information.

To assess the internal consistency of the survey instrument, Cronbach's Alpha reliability coefficients were calculated for the overall scale and for the three main phases (pre-class, in-class, and post-class). The overall scale demonstrated high internal consistency (α = 0.91). Reliability coefficients for the pre-class (α = 0.88), in-class (α = 0.93), and post-class (α = 0.86) phases also indicated acceptable to high reliability levels. These values confirm that the measurement framework possesses strong internal consistency.

Percentage Distribution Data for the Scales

Analyses Related to the Lesson Preparation Phase

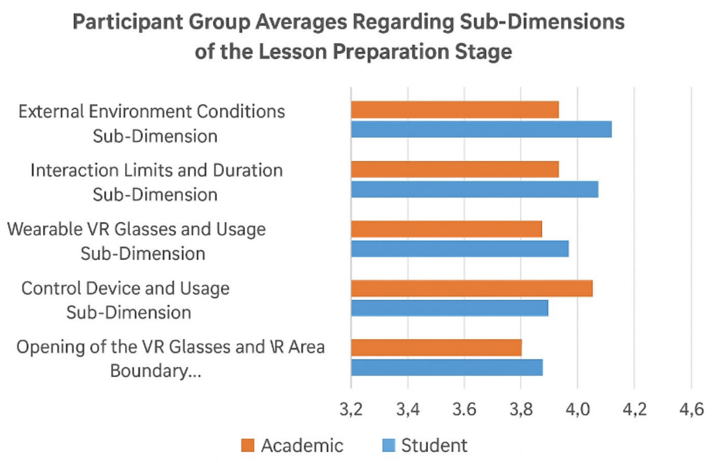

Figure 5. Comparison of participant groups regarding the lesson preparation phase.

Under the heading "Lesson Preparation Phase," participants' responses were analyzed in relation to the sub-dimensions examined in the study. The analyses are detailed below:

In the sub-dimension "Activation of the VR Headset and Boundary Setup," participants gave the highest mean score (4.10) to the statement "Defining the VR boundary is important for a safe learning experience," while the lowest mean score (3.10) was given to the statement "Wireframe lines negatively affect the virtual reality experience."

Within the "Interface Interaction" dimension, the highest mean score (4.20) was given to the statement "Creating a personalized user interface positively influences the experience," while the lowest mean score (3.60) was associated with the statement "The current interface is difficult to understand and should be simplified."

In the "Controller Use" dimension, the highest mean score (4.45) was attributed to the statement "Customizable joystick buttons can reduce adverse effects such as dizziness," whereas the lowest score (3.20) was assigned to the statement "The number of buttons on the controller is excessive."

For the "VR Wearable Headset and Use" sub-dimension, participants assigned the highest mean score (4.40) to the statement "The headset should be made of breathable, anti-fog materials," and the lowest mean score (3.90) to "The use of a cooling fan is necessary."

In the "Interaction Boundaries and Duration" dimension, the highest score (4.40) was given to the statement emphasizing "the importance of high-speed internet access and user-headset pairing for safety." The lowest score (2.80) was given to the statement "Participants should be able to join the lesson without passwords or restrictions."

In the "External Environmental Conditions" dimension, the highest score (4.25) was given to the statement "Natural light effects and ambient elements positively affect learning," while the lowest score (3.15) was assigned to the statement "External factors are distracting," with most responses marked as "Neutral."

Overall, participants responded to the statements regarding the lesson preparation phase with a mean score of 3.98, corresponding to the level of "Agree."

Analyses Related to the Lesson Phase

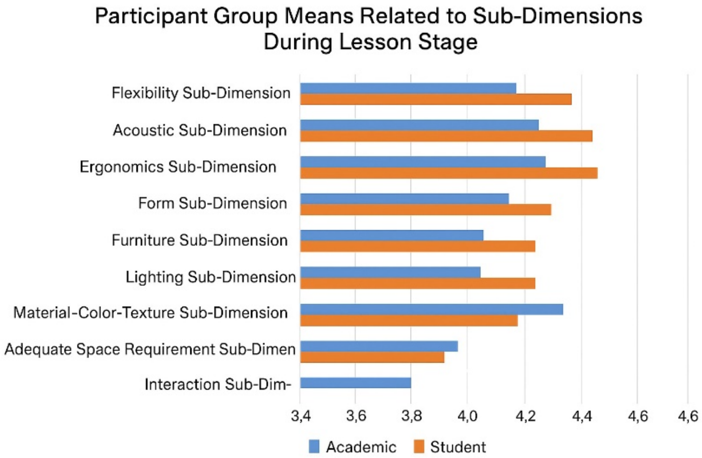

Figure 6. Comparison of results related to the lesson phase across participant groups

Under the heading "Lesson Phase," participants' views regarding the sub-dimensions were analyzed in detail. The results are presented below.

In the Interaction sub-dimension, the highest mean score (4.25) was assigned to the statement suggesting that instructors should be notified when a student removes their VR headset during class. The lowest mean score (3.30) was related to the desire to move freely through walls and avatars in the virtual environment.

In the Adequate Space Requirement sub-dimension, participants assigned the highest average rating (M = 4.50) to the statement underscoring the significance of volume, dimensionality, and scale within virtual environments.The lowest mean score (3.90) was assigned to the statement suggesting that physical space should be restricted.

In the Material-Color-Texture sub-dimension, the highest mean scores (4.40) were associated with statements on the significance of material types and the harmony of color and texture in terms of aesthetics and learning processes. The lowest mean score (3.10) was given to the statement suggesting that the use of glossy materials has a positive effect.

In the Lighting sub-dimension, participants assigned the highest average rating (M = 4.65) to the statement highlighting the critical role of lighting in virtual learning environments, while the lowest score (3.70) was related to the suggestion that artificial lighting should be directed from above.

In the Furniture sub-dimension, the highest mean score (4.40) was attributed to the statement that furniture should support users' freedom of movement, while the lowest score (4.25) was given to the statement about seating arrangements supporting group work.

In the Form sub-dimension, the highest mean score (4.20) related to the functionality of furniture, whereas the lowest score (3.60) concerned the acceptability of unconventional furniture and equipment forms.

In the Ergonomics sub-dimension, the highest score (4.40) was given to the statement that seating arrangements should allow users to follow digital content comfortably. The lowest mean score (4.20) was assigned to the statement on the accessibility of personal equipment.

In the Acoustics sub-dimension, t he statement underscoring the significance of echo-prevention measures for enhancing speech clarity obtained the highest mean score (M = 4.35), while the lowest (4.25) was given to the statement suggesting that acoustic control should be customizable.

In the Flexibility sub-dimension, the highest score (4.25) was associated with the statement that flexible seating arrangements should adapt to different theoretical approaches. The lowest score (4.00) was given to statements advocating for spatial arrangements and lighting to be capable of being modified according to individual preferences.

Overall, participants expressed agreement with the lesson phase statements, with an average score of 4.09, corresponding to the "Agree" level.

Analyses Related to Post-Lesson Phase

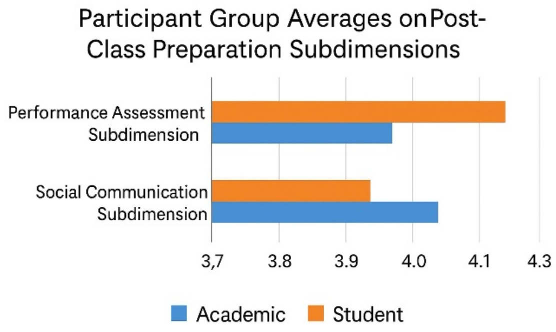

Figure 7. Comparison of Post-Lesson Phase Results According to Participant Groups

In the study, participants' opinions regarding the sub-dimensions examined under the "Post-Lesson Phase" were analyzed. The detailed analysis is presented below

In the Social Interaction sub-dimension, participants gave the highest average score (4.15) to the statement that interaction with other students' avatars during the virtual lesson is necessary. The lowest average score (3.90) was given to the statement suggesting that students' avatars being animated is a positive feature. In both cases, participants expressed agreement with the statements.

In the Performance Evaluation sub-dimension, the highest average score (4.15) was assigned to the statement emphasizing the importance of spatial adequacy—volume, size, and scale—of virtual learning environments. The lowest average score (4.05) was attributed to the statement that physical space constraints should exist in such environments. Participants generally showed positive consensus in this sub-dimension as well.

Overall, the mean evaluation score for the post-lesson phase was 4.07, indicating that participants generally agreed with the statements related to this phase.

Analysis of the General Information Section

- When examining participants' opinions on the impact of colors on concentration, 45 percent indicated that blue and 45 percent that green improved focus, while 60 percent favored white, 35 percent preferred pastel tones, and 45 percent identified neutral colors as enhancing concentration. Among these, white was the most widely accepted color in terms of its positive influence on focus.
- Regarding the motivational effects of textures used in virtual learning environments, 85 percent of participants found wood, 65 percent found fabric and glass, 40 percent found metal, 30 percent found marble, 25 percent found digital finishes, and 20 percent found concrete and plastic textures to be motivating.
- In terms of material preferences, 35 percent of participants favored the use of natural materials, while 65 percent preferred a combination of natural and digital materials.
- As for features that enhance the learning experience, 75 percent emphasized interactive learning, 65 percent access to diverse materials, 60 percent favored real-world simulations, 50 percent flexibility in the learning process, and 40 percent highlighted peer interaction and collaboration.
- In terms of aspects in need of improvement, 75 percent of participants pointed to the need for reducing technical issues. This was followed by ease of equipment use (70 percent), more realistic simulations (60 percent), social interaction, motivation-enhancing features, and security/privacy concerns (each at 55 percent).
- Among the features participants were most satisfied with, 90 percent valued the novelty of the learning experience. This was followed by visual design and aesthetics (70 percent), color and lighting arrangements (55 percent), interior materials and texture choices (50 percent), furniture and layout ergonomics (35 percent), and sound and acoustic qualities (20 percent).
- Regarding preferred points of initial access to the virtual education environment, 35 percent of participants favored a waiting area, another 35 percent preferred a pre-class social area with peers, 20 percent wanted to be directed straight into the classroom, while 5 percent selected a queue/waiting line, and another 5 percent opted for an entertainment/game area.

Group Difference Analyses

In examining group differences, independent samples t-tests were conducted for two-group comparisons, whereas one-way ANOVA was employed for analyses involving three or more groups.

Table 1. Results of the t-Test for the Lesson Preparation Stage

Dimensions	**Group**	**n**	**X̄**	**Ss.**	**t-ist**	**p**
VR Headset Activation and VR Area Boundary Subdimension	Student	10	3,88	0,21	1,172	0,256
	Academic	10	3,70	0,42		
Interface Encounter Subdimension	Student	10	3,93	0,34	0,702	0,492
	Academic	10	4,07	0,49		
Control Device Usage Subdimension	Student	10	3,90	0,27	0,927	0,366
	Academic	10	3,73	0,53		
VR Wearable Headset and Usage Subdimension	Student	10	4,02	0,32	2,470	**0,024***
	Academic	**10**	**4,38**	**0,33**		
Interaction Boundaries and Durations Subdimension	Student	10	3,99	0,23	1,311	0,206
	Academic	10	4,17	0,39		
External Environmental Conditions Subdimension	Student	10	3,80	0,28	0,978	0,341
	Academic	10	3,97	0,46		
Overall Dimension of the Pre-Class Preparation Phase	Student	10	3,92	0,14	0,711	0,491
	Academic	10	4,00	0,34		

*Significant difference at $p < 0.05$ level.

Upon examining Table 1, a statistically significant difference was observed in the sub-dimension Wearable VR Headset and Its Use in terms of participant type ($p < 0.05$). In this sub-dimension, the mean score for participants identified as "Academics" was found to be significantly higher ($\bar{X} = 4.38 \pm 0.33$). This result indicates that academic participants had a more positive experience regarding the use of wearable VR headsets compared to students.

Table 2. t-Test Results for the Course Phase

Dimensions	Group	n	X̄	Ss.	t-ist	p
Interaction Sub-Dimension	Student	10	3,80	0,51	0,963	0.989
	Academic	10	3,83	0,72		
Adequate Space Requirement Sub-Dimension	Student	10	4,13	0,56	0,620	0,543
	Academic	10	4,25	0,31		
Material-Color-Texture Sub-Dimension	Student	10	4,11	0,30	0,862	0,400
	Academic	10	3,97	0,43		
Lighting Sub-Dimension	Student	10	4,06	0,33	0,618	0,544
	Academic	10	4,16	0,39		
Furniture Sub-Dimension	Student	10	4,17	0,45	1,604	0,126
	Academic	10	4,50	0,48		
Form Sub-Dimension	Student	10	3,98	0,46	0,671	0.995
	Academic	10	3,99	0,48		
Ergonomics Sub-Dimension	Student	10	4,25	0,35	0,583	0,567
	Academic	10	4,35	0,41		
Acoustics Sub-Dimension	Student	10	4,13	0,32	1,768	0,094
	Academic	10	4,47	0,50		
Flexibility Sub-Dimension	Student	10	4,07	0,34	0,159	0,876
	Academic	10	4,10	0,57		
Overall Dimension of the Course Phase	Student	10	4,08	0,33	0,628	0,538
	Academic	10	4,18	0,37		

*Significant difference at $p < 0.05$ level.

An analysis of Table 2 indicates that no statistically significant differences were observed among participant groups regarding the sub-dimensions, interaction, spatial adequacy, material-color-texture, lighting, furniture, form, ergonomics, acoustics, flexibility, and the overall dimension of the course phase ($p > 0.05$). This indicates that both students and academic staff exhibited comparable evaluations across these dimensions during the course phase of the VR-supported educational experience.

Table 3. Post-Class Phase Independent Samples t-Test Results

Dimensions	Group	n	$\bar{X}$	Ss.	t-ist	p
Social Interaction Subdimension	Student	10	4,17	0,36	0,978	0,341
	Academic	10	3,93	0,66		
Performance Evaluation Subdimension	Student	10	3,95	0,37	1,555	0,137
	Academic	10	4,25	0,49		
Overall Dimension of the Post-Class Phase	Student	10	4,06	0,30	0,189	0,852
	Academic	10	4,09	0,46		

As observed in Table 3, no statistically significant difference was found between participant types in terms of the social communication, performance evaluation, and overall post-class phase dimensions ($p > 0.05$).

According to the results of the independent samples t-test analyses, a statistically significant difference was identified between student and academician groups only in the "use of wearable VR headset" sub-dimension ($p < 0.05$). In this dimension, academicians reported significantly higher mean scores compared to students. No statistically significant variations were identified in the remaining sub-dimensions or overall dimensions.

This finding suggests that both groups share relatively similar perceptions regarding the overall VR-supported educational experience, yet they may exhibit divergent experiences and approaches specifically in relation to the individual use of VR devices.

The Research Findings and Discussion

Findings Regarding the Pre-Class Phase

The data obtained in the study indicate that participants particularly prioritize safety and personalization elements during the pre-class phase. The emphasis on defining spatial boundaries for VR headset use and the preference for breathable materials suggest that participants place high importance on physical comfort and safety. The relatively low concern for wireframe lines implies a greater focus on user security over technical details. In the interface dimension, the positive impact of personalized interfaces on user experience and the difficulty in understanding existing interfaces reveal the need for more user-friendly and simplified designs. The strong preference for customizable joystick buttons reflects an emphasis on individual ergonomic expectations, while the negative perception of having too many buttons indicates the importance attributed to ease of use.

In addition, although overall satisfaction levels were high, several participants informally reported temporary visual fatigue toward the later stages of extended VR use, indicating that immersion duration may influence attention sustainability.

Findings Regarding the In-Class Phase

The recognition of the importance of a notification mechanism when the VR headset is removed during class demonstrates that continuous communication and control in virtual environments are considered critical safety elements. The limited support for unrestricted movement implies a preference for structured and rule-based environments, perceived as more effective and secure. The high importance attributed to spatial adequacy suggests that participants expect virtual environments to mimic the perception of physical space. Preferences regarding materials, colors, and textures highlight the significance of aesthetics and support for learning, indicating that VR environments should offer not only functionality but also emotional experience. The lower support for glossy materials suggests sensitivity to issues such as eye strain and distraction. The emphasis on lighting underscores the importance of visual comfort, while the lower emphasis on the direction of artificial lighting indicates that its adequacy is deemed more critical than its orientation.

Findings Regarding the Post-Class Phase

The value attributed to post-class social interaction among avatars indicates that socialization within virtual learning environments has a substantial influence on both motivation and learning achievement. The relatively lower positive evaluation of avatar mobility may be associated with expectations of visual simplicity and focus. Prioritization of functionality and freedom of movement in furniture and form factors suggests that conventional comfort expectations persist in virtual environments. The importance placed on ergonomic and acoustic arrangements reflects the necessity of spatial configurations that support the learning process. The demand for personalization further indicates that standard solutions may not be adequate for all users.

Findings Regarding General Information

In the general information section, the color white was most frequently mentioned as enhancing concentration, suggesting a preference for neutral and non-distracting colors. The strong preference for combining natural and digital materials indicates that participants wish to experience both a sense of naturalness and technological engagement in VR environments. Among the features that support the learning experience, the prominence of interactive learning reflects a desire for active participation. The prioritization of reducing technical issues as a key area for improvement indicates that infrastructural shortcomings negatively affect the learning process. Finally, the high satisfaction with VR as a novel learning experience demonstrates that it is still perceived as an innovative and exciting option. However, the need for improvement in areas such as furniture, ergonomics, sound, and acoustics remains evident.

This study aimed to develop design criteria for virtual learning environments on online VR platforms and found that user experience is shaped around the axes of safety, comfort, personalization, and social interaction. The findings are consistent with existing literature on the influence of physical environmental components on learning processes, particularly highlighting the importance of spatial boundary clarity, ergonomic material selection, and proper lighting in enhancing learning efficiency. The emphasis on social interaction in the post-class phase reveals that virtual learning environments should not only serve individual learning but also support community dynamics. Unexpectedly, the lower sensitivity to technical details suggests that users primarily focus on fundamental needs such as safety and comfort. However, the study's small sample size and its focus on particular VR platforms represent constraints that may limit the broader applicability of the results. Future investigations should encompass more diverse participant groups, employ longitudinal methodologies, and incorporate cross-platform comparative analyses. In conclusion, this study underscores the necessity of adopting user-centered, flexible, safe, and interaction-oriented approaches in shaping virtual learning environment design and providing both theoretical and practical contributions to the existing body of literature

Spatial Design Criteria for Virtual Learning Environments

In the design guidelines study, the content should be addressed under two main categories: spatial design and equipment design. This distinction stems from the necessity of evaluating virtual learning environments through a holistic approach. Although the equipment design section was ultimately excluded from the final version of the text, its impact on the learning experience remains significant and cannot be disregarded. Designing an effective user experience in virtual learning environments is not limited to optimizing the visual and functional qualities of the digital space alone. The quality of the hardware and interface components that enable users to access these environments also directly influences the learning process.

It should be noted that the design criteria presented in Table 4 are not intended as rigid prescriptions but rather as context-sensitive guidelines derived from empirical findings. The applicability of each criterion may vary depending on lesson type, user profile, duration of use, technological infrastructure, and safety considerations. Therefore, these criteria should be interpreted as flexible recommendations that can be adapted to specific educational scenarios rather than universally fixed design rules.

Table 4. Design Criteria for Virtual Learning Environments

Spatial Design		
Physical Space Requirements	**Design Criteria**	**Design Requirement**
Access	Access to the virtual environment	The absence of conditions such as links, codes, or passwords for users to access lessons facilitates a faster process and ensures uninterrupted participation. Therefore, direct and easy access to lessons should be provided..
	Classroom seat selection	Allowing users to freely choose their spaces or seats within the virtual classroom personalizes the user experience and enhances the sense of belonging. Therefore, users should be enabled to select their seats freely in the virtual classroom.
	Free movement opportunity	Free movement between rows provides users with physical comfort while enhancing communication, interaction, and a sense of belonging. Therefore, the design should consider enabling users to move freely between the rows.
	Technological tools	Keeping technological tools up-to-date optimizes digital interaction and ensures an efficient learning environment. Therefore, all technological equipment should be fully prepared and updated prior to the commencement of the educational activities.
	Technological infrastructure	A robust internet infrastructure optimizes the user experience by ensuring uninterrupted continuity of lessons. Therefore, high-speed internet and seamless network access must be provided.

Spatial Design		
Physical Space Requirements	**Design Criteria**	**Design Requirement**
	Personal VR headset	Eye recognition through VR headsets enhances class discipline and ensures secure participation. Each user should undergo personalized eye identification, preventing unauthorized access on behalf of others
	Transition to the classroom.	The design of a waiting area during the transition to the virtual classroom ensures an orderly and controlled start to the lesson. Therefore, a waiting area should be planned for virtual classroom entry.
	Alternative learning experience	The provision of interactive learning experiences enhances user engagement and makes interactions more effective. Therefore, priority should be given to interactive learning experiences.
	Technical condition	Resolving technical issues increases continuity and efficiency in digital interaction. Therefore, efforts to address technical problems prior to the lesson should be prioritized.
	Avatar mobility	Allowing avatars to move freely enhances flexibility and comfort within the learning environment, thereby improving the overall experience. Therefore, avatars should be enabled to move freely before, during, and after the lesson.
	Freedom of movement	Allowing users to move freely within the classroom without colliding with walls or avatars makes the overall experience smoother and more comfortable. Therefore, users should be enabled to navigate freely without encountering obstacles.
	Course discipline	Sending a notification to the instructor when users remove their VR headset enhances class monitoring and participation discipline. Therefore, a system should be implemented to notify the instructor whenever the headset is removed
	User control	Sending a notification to the instructor when users keep their eyes closed for an extended period helps manage class participation and discipline more effectively. Therefore, a system should be implemented to notify the instructor if a user's eyes remain closed for a prolonged time.
External environmental conditions	External factors	In virtual learning environments, the controlled regulation of external factors (such as scenery, sounds, etc.) contributes to maintaining an optimal level of attention. Therefore, environmental distractions should be minimized.
	Natural lighting effect	The use of natural light effects (e.g., daylight simulation) enhances user interaction by providing a realistic and immersive experience. Therefore, natural light simulations should be prioritized in virtual learning environments.
	Environmental characteristics	The use of atmospheric (ambient) features such as relaxing backgrounds and soothing colors enhances user comfort and positively influences learning processes. Therefore, the implementation of supportive atmospheric (ambient) design elements should be ensured.
Need for adequate space	Volume, size, and scale	The volume, dimensions, and scale of a virtual learning environment significantly enhance user comfort by allowing participants to move freely and access learning materials and fellow users with ease. The spatial parameters should be defined to provide adequate area per person, accommodating both group and individual activities, while ensuring sufficient volume that does not hinder user interactions.
	Spatial boundaries	Allowing users to pass through avatars and walls in the virtual environment enhances interaction and the dynamic nature of the space, thereby enriching the user experience. Therefore, users should be granted freedom of movement within the virtual setting.
	Per capita space	Physical space limitations in virtual learning environments enhance user safety and well-being. To prevent issues such as collisions and restricted movement within virtual educational settings, a minimum area of 1.86 m^2 per user should be allocated. (This figure is determined based on the minimum standards outlined in the Educational Facilities Guidelines.)
	Diverse use of space	In virtual learning environments, providing adequate space for both individual and group work maximizes learning effectiveness and user interaction. Therefore, sufficiently spacious areas should be designed to accommodate different types of lessons.

Spatial Design		
Physical Space Requirements	**Design Criteria**	**Design Requirement**
Material–colour–texture	Type of material	The appropriate selection of materials used for walls, ceilings, floors, and furniture in virtual learning environments enhances the perceptual quality of the space. Therefore, materials should be carefully chosen to strengthen spatial perception. The combined use of natural and digital materials in virtual learning environments improves visual comfort and focus. Hence, the integration of both natural and digital materials should be ensured. Wood textures enhance spatial perception and serve as a motivational element for users. Therefore, wood textures should be preferred, considering their motivating effect.
	Colour	In virtual learning environments, appropriate color selection enhances attention levels and spatial perception according to the nature of the lesson. Neutral and calm colors support focus in theoretical courses, whereas more vibrant colors should be employed for creative activities. Therefore, color choices must be made in alignment with the type of lesson. The use of white color positively influences perception and concentration, thereby improving learning efficiency. For this reason, white should be preferred due to its focus-enhancing effects.
	Texture	The selection of textures appropriate to the type of lesson and user group directly influences spatial perception and focus during the lesson. Soft-looking textures help to concentrate attention, whereas hard-looking textures may cause distraction. Therefore, textures should be carefully chosen based on the characteristics of both the users and the lesson content.
	Perception of real material	The realistic simulation of interior finishes provides a more interactive and authentic experience. Therefore, the use of realistic simulations should be prioritized.
	Material glossiness	The preference for glossy materials enhances the visual vibrancy of the space and increases user attention, thereby fostering a positive interaction. Therefore, the use of glossy materials should be prioritized to strengthen spatial perception and support the learning experience.
	Material smoothness	The use of smooth materials enhances the realism and natural perception of the space, thereby strengthening the user experience. Therefore, the application of smooth materials should be prioritized to support the visual quality and level of interaction within the environment.
	Compatibility	The harmony between textures and colors enhances the aesthetic coherence of the space, thereby increasing users' connection to the environment and their level of focus. Therefore, textures and colors should be carefully selected to ensure compatibility.
Lighting	Importance of lighting	Proper lighting design enhances learning efficiency by improving users' focus on the lesson and strengthening their spatial perception. Well-planned lighting provides visual comfort and prevents distractions. Therefore, lighting design should be carefully planned and tailored to the specific needs of the lesson.
	Natural light simulation	The use of natural light simulations enhances the sense of realism in the space, enabling users to establish a stronger interaction with the virtual environment and supporting their perception of time and space. Therefore, natural light simulations such as daylight and nighttime lighting should be incorporated.
	Natural lighting	The use of natural lighting improves the spatial perception and overall atmosphere, providing a bright and efficient learning experience. Therefore, natural lighting design should be prioritized.
	Natural lighting - window	The incorporation of window usage in natural lighting design enhances the sense of real space, spatial perception, and user comfort, creating a more vibrant and effective atmosphere. Therefore, the use of window simulations should be ensured in natural lighting design.
	Direction of artificial lighting	The orientation of artificial lighting in accordance with real-life conditions optimizes the user experience and enhances spatial perception. Therefore, artificial lighting design should be planned with the light directed from above.
	Light colour	The use of warm white light in lighting design protects eye health, enhances spatial perception, and improves the user experience. Therefore, the light color should be chosen as warm white.
	Light intensity	Adequate light intensity positively influences the spatial atmosphere and user experience. Therefore, light intensity should be planned at medium or higher levels.

Spatial Design		
Physical Space Requirements	**Design Criteria**	**Design Requirement**
	Lighting design	Realistic lighting design enhances the authenticity of the space, allowing the environment to be perceived as more natural and effective. Therefore, lighting should be designed in accordance with the principles of the physical world.
Furniture	Furniture design	In virtual learning environments, furniture should be planned according to different types of lessons, enhancing the functionality of the space and improving the user experience. Therefore, multipurpose seating arrangements should be provided in virtual education spaces.
	Relationship between furniture and space	Furniture designed in harmony with the interior space enhances aesthetic perception and positively influences users' interactions with the environment. Therefore, in furniture design, the coherence of form, color, and texture should be meticulously planned.
	Furniture layout	The arrangement of furniture in accordance with internal spatial circulation enhances the ergonomics of the environment, improving users' freedom of movement and comfort. Therefore, proper positioning of furniture should be ensured.
Form	Importance of form	The appropriate selection of form in virtual learning environments significantly enhances the aesthetics and perception of the space. Therefore, form design should adopt a user-centered approach
	Use of form	The use of diverse forms beyond classic shapes (such as squares, rectangles, etc.) enhances user motivation and enriches the learning experience. This variety increases the dynamism of the space, capturing users' attention and providing a more interactive learning environment. Therefore, incorporation of diverse forms should be ensured in virtual learning environments.
	Form of furniture and equipment	The functional design of furniture and technological equipment forms enhances user perception and positively influences the learning experience. Therefore, both functional and visually engaging forms should be prioritized.
	Furniture functionality	Furniture should be designed in accordance with the function of the space and the nature of the lesson, as this enhances lesson efficiency and improves users' learning experiences. Therefore, the functions of the furniture must be determined based on the specific requirements of the lesson.
Ergonomics	Ergonomics of virtual learning environments	Proper positioning of equipment enhances accessibility within the space and improves users' attention levels. Therefore, interactive whiteboards and screens should be installed at heights easily reachable by users, while computers and tablets on desks should be arranged ergonomically to accommodate seated postures.
	Personal equipment	Effective arrangement of seating and digital planning significantly enhances the efficiency of the lesson. Therefore, the seating layout should be designed to ensure that the digital projector is optimally visible and audible to all participants.
Acoustics	Acoustic treatment	Acoustic arrangements designed with consideration for adverse conditions such as internet interruptions significantly enhance volumetric acoustic comfort. Therefore, acoustic systems should be planned to be resilient against unfavorable connectivity conditions.
	Acoustic design	Designs that consider sound levels significantly enhance the acoustic performance of the lesson. Therefore, effective implementation of echo-reducing acoustic solutions should be ensured.
	Personalized acoustic control	Distance and directional sound adjustments in VR headsets significantly affect users' auditory perception. Therefore, sound settings should be made customizable.
Flexibility	Diverse working environments	Designing the seating arrangement to be flexible enhances the functionality of the space. Therefore, virtual learning environments should incorporate adaptable seating layouts that can accommodate various types of educational activities.
	Personalizable seating	Allowing users to arrange desks and chairs according to their preferences increases the flexibility and comfort of the space. Therefore, users should be granted the freedom to modify the spatial layout based on their individual needs.
	Customizable lighting	The ability for users to personalize the lighting level significantly enhances user comfort. Therefore, the lighting intensity should be designed to allow manual adjustment.
Social communication	Social space	The presence of open spaces where users can socialize at the end of virtual lessons strengthens communication. Therefore, areas should be designated to allow users to socialize and move freely.

Spatial Design		
Physical Space Requirements	**Design Criteria**	**Design Requirement**
	Selection of social space	Allowing users to select the open spaces for socializing at the end of virtual lessons offers a user-friendly approach. Therefore, users should be given the opportunity to designate areas for social interaction according to their personal preferences and needs.
	Post-class teleportation	At the conclusion of virtual lessons, users should be allowed to decide whether to be directed to virtual waiting rooms or computer interfaces.
Performance evaluation	Class discipline	After virtual lessons, reporting users' attendance duration to the instructor enhances class discipline. Therefore, the duration of users' interaction with the VR headset should be recorded and communicated to the instructor as an attendance report.
	Assignment of grades	Establishing participation rules during lessons plays a crucial role in maintaining class discipline. In this context, students who comply with the participation rules (excluding those affected by connection issues) at the end of VR virtual lessons should have their performance reflected in their course grades.

DISCUSSIONS

The findings of this study reveal that virtual reality (VR)-supported learning environments provide a distinctive alternative to conventional two-dimensional (2D) digital education tools such as Microsoft Teams or Zoom. Unlike traditional communication software, VR enables embodied interaction, spatial immersion, and multisensory engagement, allowing learners to become active participants rather than passive observers. This spatial dimension enhances the realism of the learning process and strengthens users' cognitive and emotional connection to the content. The mixed-method approach adopted in this study, integrating both qualitative and quantitative data collection techniques, enabled a holistic evaluation of users' spatial perceptions and behavioral responses within the virtual environment.

However, the primary limitation of this study is the relatively small sample group, composed of participants from a single academic discipline. The main reason for this limitation lies in the lengthy duration of each VR course experiment, which required an average of 120 minutes of interaction per participant. Due to the time- and resource-intensive nature of these experimental sessions, the study was conducted with a group of 20 participants. Although the participants' extensive experience with online learning and familiarity with VR technologies offered a significant advantage, the limited sample size constrains the generalizability of the findings across different educational levels and disciplines. Future research should include larger and more diverse participant groups representing various academic fields and age ranges to test the validity of the design criteria developed in this study.

In addition, the study should be positioned within an exploratory research framework. The immersive nature of the VR sessions, requiring approximately 120 minutes of individual participation, significantly limited the feasible sample size due to time and technical constraints. Therefore, this research was designed as an initial exploratory investigation aimed at developing preliminary spatial design criteria rather than achieving broad statistical generalization. The primary objective was to identify foundational architectural parameters for VR learning environments, which may serve as a basis for larger-scale empirical studies in the future.

From a methodological perspective, the VR-based experimental approach adopted here offers notable advantages over conventional survey-based or 2D screen evaluations. This method allows for the comprehensive observation of user behavior, spatial orientation, and comfort responses within an immersive context. Although long-term use of VR headsets may cause visual fatigue or mild discomfort compared to 2D screens, participants consistently reported that the immersive environment provided a much more realistic, interactive, and memorable experience. When exposure duration is carefully managed, the advantages of "presence" and "embodied interaction" in VR environments clearly outweigh potential physical discomfort.

Nevertheless, it should be emphasized that not every technological infrastructure or VR platform is equally suitable for educational use. Variables such as software stability, graphical performance, motion tracking accuracy, and network requirements can significantly influence the overall quality of the learning experience. For instance, platforms primarily designed for gaming may lack the ergonomic or pedagogical features required for sustained educational engagement. In contrast, education-oriented platforms such as *Engage* or *Mozilla Hubs* provide structured tools for content delivery and collaborative interaction, aligning more closely with academic learning objectives.

While the findings highlight the transformative potential of VR-based education, they also draw attention to existing challenges. On the positive side, VR environments strengthen social presence, promote active learning, and materialize the constructivist paradigm by simulating real-world spatial interactions. On the other hand, accessibility issues, equipment costs, and technical skill requirements may limit scalability. Therefore, future studies should aim to balance technological innovation with inclusivity, developing solutions that enhance user comfort and accessibility. By doing so, a holistic and sustainable virtual learning experience can be extended to broader learner communities.

Although immersive VR environments offer enhanced spatial presence and engagement, extended exposure duration may introduce certain cognitive and physiological challenges. In the present study, each participant engaged in approximately 120 minutes of VR-based instruction. Prolonged headset use may potentially lead to visual fatigue, temporary attention fluctuation, mild discomfort, or reduced concentration over time. While participants generally reported high levels of satisfaction and engagement, the duration of immersive exposure should be considered as an important design parameter in VR-based educational settings. Careful planning of session length is therefore essential to sustain cognitive performance and user well-being.

CONCLUSION

This study aimed to examine the impact of the physical environmental components of VR-supported virtual learning environments on the learning experience and to develop user-centered design criteria. The findings revealed that safety, ergonomics, personalization, and social interaction are critical factors that directly influence learning efficiency in VR-based educational settings. Data obtained through the survey instrument developed within the scope of the study demonstrated an increasing level of user awareness regarding the design of virtual learning spaces.
In particular, the personalization of spatial boundaries, the use of ergonomic equipment, and user-friendly interface design were identified as key elements enhancing the effectiveness of VR environments. Reducing the reliance on physical control elements and incorporating hand- and finger-based gesture interactions were found to positively influence user experience. These results, while consistent with existing literature, offer a new perspective on the effective design of virtual learning environments.

Accordingly, the developed design guide aims to enhance the quality of virtual learning environments and improve overall user experience. By addressing both spatial and hardware-related design dimensions holistically, the study introduces an innovative methodological approach and demonstrates strong applicability in the fields of architecture, interior architecture, and educational technology. Furthermore, it extends beyond technology infrastructure–focused approaches by exploring in depth the relationship between physical environmental qualities and user comfort.

The proposed design guide may function as a practical framework for architects, interior architects, educational technologists, and VR platform developers. It can be utilized as (1) a preliminary design checklist during early-stage virtual classroom development, (2) an evaluative tool for assessing the spatial quality of existing VR learning environments, and (3) a decision-support reference in interdisciplinary collaborations between design and education professionals. Rather than prescribing fixed spatial solutions, the guide aims to support context-aware design thinking and structured decision-making in immersive educational environments.

In conclusion, this study opens new discussions on the social implications of digitalization and the growing use of VR technology in education, while proposing design criteria that support the accessibility and effectiveness of virtual learning environment.

RECOMMENDATIONS

Broader and More Diverse Samples; The number of participants in this study was limited due to the extended duration of individual VR sessions (approximately 120 minutes per participant). Future research should aim to optimize experimental procedures to include larger and more diverse participant groups representing different disciplines, age ranges, and educational levels, thereby enhancing the generalizability of the findings.

Inclusion of Participants from Various Disciplines; Since this study involved participants from a single academic discipline, the results may not be fully generalizable to other contexts. Future studies should include participants from multiple disciplines to enable cross-disciplinary comparisons and to provide a more comprehensive understanding of how VR-based learning impacts different fields.

Longitudinal Impact Analyses; The cognitive and affective effects of VR-based learning environments may vary over time. Therefore, future studies should employ longitudinal designs to examine the long-term impacts, knowledge retention, and behavioral outcomes associated with immersive learning experiences.

Integration of Emerging Technologies; Given the rapid evolution of VR technologies, future research should incorporate next-generation devices and interaction systems such as haptic feedback, eye-tracking, and full-body motion capture. This integration would enable more sophisticated analyses of user engagement, embodiment, and spatial cognition.

Mixed-Methods Approaches; To capture the multifaceted nature of user experience in VR learning environments, future studies are encouraged to adopt mixed-method approaches that combine quantitative performance data with qualitative feedback, offering a holistic understanding of both cognitive and emotional engagement.

Given that immersive VR exposure lasted approximately 120 minutes per participant in this study, future implementations should consider dividing instructional content into shorter modules (e.g., 20–30-minute sessions) supported by scheduled breaks. Such segmentation may help prevent visual fatigue, maintain attention levels, and enhance long-term cognitive engagement in immersive learning environments.

Ethics and Consent: Ethical approval for this study was obtained from the Executive Board of the Graduate School of Science at Mimar Sinan Fine Arts University with the decision dated 26.01.2024 and numbered 3/5-c, based on the Scientific Research Ethics Declaration Form registered under number 148835.

Acknowledgments: The author would like to express sincere gratitude to all participants who dedicated their time and energy to take part in the extended VR-based learning sessions. Their patience, commitment, and thoughtful engagement throughout the process made this study possible. The valuable insights they shared not only enriched the research outcomes but also contributed meaningfully to the development of user-centered design principles for virtual learning environments.

REFERENCES

Allen, I. E., & Seaman, J. (2011). Going the distance: Online education in the United States, 2011. Sloan Consortium.

Anderson, T. (2008). The theory and practice of online learning. AU Press.

Arlı, Z. K., & Nazik, İ. (2001). Eğitimde ve psikolojide ölçme ve değerlendirme. Anı Yayıncılık.

Bates, A. W. (2005). Technology, e-learning and distance education. Routledge.

Dede, C. (2009). Immersive interfaces for engagement and learning. Science, 323(5910), 66–69. https://doi.org/10.1126/science.1167311

Gay, L. R. (1987). Educational research: Competencies for analysis and applications (3rd ed.). Prentice Hall.

Galan, J. (2017). Educational architecture and emerging technologies: Innovative classroom models. University of Extremadura (Spain) & Metropolitan University AGMUS (Puerto Rico-USA).

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. Educause Review, 27.

Johnson, L., Adams Becker, S., Estrada, V., & Freeman, A. (2016). NMC Horizon Report: 2016 Higher Education Edition. The New Media Consortium.

Karal, H., Çebi, A., & Turgut, Y. E. (2011). Students' opinions on blended learning and its implementation in terms of their learning styles. Education and Information Technologies, 16(1), 5–23. https://doi.org/10.1007/s10639-009-9104-7

Kurtuluş, M. (2024). Analysis of virtual education spaces in online VR platforms in terms of physical environmental components and proposal of design criteria for virtual education spaces (Doctoral dissertation, Mimar Sinan Fine Arts University, Graduate School of Education, Istanbul).

Kurtuluş, M., & Tekin, Ç. (2026). Sanal Gerçeklik Destekli Eğitim Alanlarında Fiziksel Çevre Bileşenlerine Dayalı Kullanıcı Deneyiminin Karma Yöntem Yaklaşımıyla Analizi. *Dijital Çağda Öğrenme ve Öğretme Dergisi* , *1* , 84-100. https://doi.org/10.53850/joltida.1745019

Laurillard, D. (2012). Teaching as a design science: Building pedagogical patterns for learning and technology. Routledge.

Lim, C. P. (2012). Leadership for 21st century learning: Global perspectives from international experts. Springer.

Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014). Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis. Computers & Education, 70, 29–40. https://doi.org/10.1016/j.compedu.2013.07.033

Webster, R. (2016). Etkileşimli sanal öğrenme ortamlarında bildirimsel bilgi edinimi. Etkileşimli Öğrenme Ortamları, 24, 1319–1333. https://doi.org/10.1080/10494820.2014.994533