

Designing Immersive Virtual Interior Spaces: A System Analysis of a VR Classroom Interaction Prototype Using Unity XR Interaction Toolkit

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Virtual Reality (VR) has become a powerful medium for simulating interior environments, enabling users to experience spatial layouts, object arrangements, and environmental interactions with high fidelity. This paper presents an academic analysis of a VR Classroom Interaction system developed using Unity's XR Interaction Toolkit, focusing on how VR interaction components are integrated with interior spatial design principles. The prototype features an immersive classroom environment where users can navigate the space, interact with furniture and stationery objects, perform door-opening actions based on realistic hinge mechanics, and access in-game UI elements. These interactions are supported by components such as XR Grab Interactable, hover-based affordance outlines, physics joints, and a custom head-bobbing locomotion script. By examining both the interaction mechanics and the spatial layout—such as object placement on desks, circulation flow within the classroom, and the architectural behavior of doors—this study highlights the role of interior design considerations in shaping user immersion and interaction clarity. The findings demonstrate that combining VR interaction frameworks with interior design principles enhances environmental realism, spatial cognition, and user experience within virtual learning spaces, providing a foundation for future VR-based interior simulations and educational environments.

Keywords— *Virtual Reality, XR Interaction Toolkit, Interior Design, Spatial Cognition, Classroom Simulation, Immersive Interaction*

I. INTRODUCTION

Virtual Reality (VR) has evolved into a powerful medium for simulating interior environments, enabling users to explore architectural spaces, manipulate objects, and engage in spatial learning through immersive interaction. Unlike traditional desktop interfaces, VR provides embodied presence—allowing users to perceive scale, proportion, depth, and circulation within a designed environment. These qualities

make VR increasingly relevant not only in gaming and training but also in the fields of interior design, architectural visualization, and educational spatial simulation (Milovanovic et al., 2020; Portman et al., 2015).

Interior design as a discipline is heavily concerned with spatial organization, object placement, ergonomics, circulation flow, and environmental legibility. When these principles are translated into VR, they significantly influence user perception, comfort, and interaction clarity. Studies have shown that VR environments with coherent interior layout improve spatial cognition and user task performance (Jeng, 2011; Kuliga et al., 2015). Classroom interiors, in particular, rely on predictable spatial structures—desks arranged for visibility, pathways optimized for movement, and objects positioned for functional proximity—all of which become essential when constructing educational VR simulations.

The VR Classroom Interaction prototype analyzed in this paper applies these interior design principles within a digital environment. Built using Unity and the XR Interaction Toolkit, the system simulates a standard classroom interior where users can enter the space, inspect desks and learning materials, interact with objects such as books and stationery, and operate architectural components like doors using realistic hinge mechanics. The user guide provides detailed descriptions of these features—including head-bobbing locomotion, hover-based affordance outlines, object grabbing, and physics-driven door behavior—offering insights into how spatial organization and interaction systems converge within the virtual classroom (User Guide, pp. 1–7)

A. Interior Design and Spatial Cognition in VR Learning Environments

The relationship between interior design and VR learning systems has been increasingly emphasized in recent literature. VR environments that incorporate realistic interior elements—such as proportional furniture, accurate room geometry, and natural object placement—enhance presence, engagement, and task realism (Radianti et al., 2020). In educational settings, spatial realism supports embodied learning, allowing students to interact with materials in ways that mimic physical classroom behavior (Makransky & Mayer, 2022).

The VR classroom in this project is designed with attention to:

- **Functional Zoning:** All interactable items (book, pencil, apple, etc.) are placed on desks where they would naturally be found.
- **Circulation Flow:** Users move through hallways and enter the classroom through a door—mirroring real educational spatial sequences.
- **Ergonomic Scale:** Objects and furniture adhere to realistic proportions to strengthen spatial cognition.
- **Architectural Behavior:** The door operates using hinge joints, reproducing real-world physical responses.

These characteristics align VR system design with established interior design approaches, enhancing immersion and supporting educational interaction fidelity.

B. VR Interaction Fidelity and Environmental Realism

High-quality VR learning environments rely on interaction fidelity—the degree to which virtual interactions resemble real-world actions (Jerald, 2015). The VR Classroom Interaction system utilizes several XR components to achieve this:

- XR Grab Interactable for direct object manipulation
- Hover Outline to indicate object affordances
- Hinge Joint + Fixed Joint to simulate realistic door mechanics
- Head-bobbing locomotion to provide embodied physical movement cues

Such interactions mimic real physical behavior, resulting in more intuitive and embodied user experiences. This is essential in interior spaces, where interaction with furniture and everyday objects forms a natural part of learning and environmental understanding.

Current VR research extensively examines learning outcomes, engagement, and virtual pedagogy. However, fewer studies address the intersection of *VR interaction design* and *interior spatial design*—especially within classroom simulations. In traditional education, interior layout strongly influences behavior, attention distribution, and task efficiency (Barrett et al., 2015). Translating these spatial qualities into VR requires careful attention to both the functional interaction systems and the interior architecture of the virtual environment.

This study is motivated by the need to:

1. Understand how interior design principles enhance VR interaction fidelity.
2. Analyze how XR components support believable interactions within classroom interiors.

3. Demonstrate that VR classroom environments can serve as testbeds for virtual interior design and educational simulation.

This paper aims to:

1. Provide a structured academic analysis of the VR Classroom Interaction prototype.
2. Examine how VR interaction systems align with interior design principles.
3. Explore how spatial layout and object placement influence presence, usability, and engagement in VR.
4. Highlight the potential of VR as a platform for designing, evaluating, and experiencing educational interiors.

II. RELATED WORK

Research in Virtual Reality (VR) has developed along multiple intersecting domains, including immersive learning, interaction fidelity, spatial cognition, and interior environment simulation. Because VR systems increasingly replicate real-world interior spaces—such as classrooms, studios, and architectural environments—recent studies emphasize the importance of combining VR interaction mechanisms with interior spatial principles to enhance user experience, presence, and environmental legibility. This chapter reviews prior work relevant to: (1) VR in educational environments, (2) interaction fidelity and embodied presence, (3) interior design in virtual environments, and (4) XR frameworks supporting these implementations.

A. VR in Education and Learning Environments

VR has been widely used to support educational activities by providing immersive, interactive, and context-rich learning environments. Radianti et al. (2020) found that VR enhances learner engagement, conceptual understanding, and cognitive immersion, particularly when environments mimic real-world learning spaces. Classroom-based VR simulations have also been explored for teacher training (Zhao et al., 2021), classroom behavior analysis (Ferdig et al., 2020), and virtual laboratory experiences.

The VR Classroom Interaction prototype described in the user guide (pp. 1–7) aligns with these research trends by placing users in a simulated educational interior where they interact with classroom furniture, stationary objects, and architectural elements such as doors. This supports experiential learning, enabling users to learn through physical engagement with the virtual environment.

Studies consistently highlight that spatial realism—accurate room proportions, logical furniture layout, and clear circulation paths—enhances the educational value of VR classrooms (Makransky & Mayer, 2022; Milovanović et al., 2020). The prototype’s use of realistic desk arrangements and object placement supports this framework.

B. Interaction Fidelity, Embodiment, and User Experience

Interaction fidelity refers to how closely VR interactions resemble real-world physical actions (Jerald, 2015). Prior research shows that naturalistic interactions, such as grabbing objects with hand-like movements, greatly enhance embodiment and reduce cognitive load (Argelaguet & Andujar, 2013; McGloin et al., 2020).

The VR Classroom Interaction system uses:

- XR Grab Interactable for direct grabbing,
- Hover Outline for object affordance cues,
- Hinge Joints for realistic door movement,
- Custom head-bobbing locomotion to simulate natural walking,

These features align with evidence showing that embodied interaction increases the sense of presence, enabling users to feel physically connected to the environment (Bowman & McMahan, 2007).

In classroom simulations, interaction fidelity is crucial for tasks such as:

- picking up learning materials,
- opening doors,
- inspecting static objects,
- navigating furniture layouts,

all of which depend on natural motor behaviors.

C. Interior Design in Virtual Environments

Interior design research emphasizes the importance of spatial organization, ergonomics, circulation flow, and object placement in shaping human behavior and environmental perception (Barrett et al., 2015; Portman et al., 2015). These principles apply directly to VR environments because interior organization affects how users navigate and interpret digital spaces.

Studies show that VR users rely on interior cues—such as furniture arrangement, room proportions, and visual hierarchy—to orient themselves and perform tasks efficiently (Kuliga et al., 2015; Jeng, 2011). When virtual spaces follow established interior design logic, users experience stronger spatial cognition and environmental legibility.

In the VR Classroom Interaction system:

- Interactable objects (book, pencil, apple, etc.) are placed on desks, reflecting real-world functional work zones (pp. 3–5).
- Users enter through a hallway and turn right into a classroom, demonstrating interior circulation design.
- The door’s realistic swinging motion reflects architectural authenticity.

- Head bobbing influences perceived spatial proportion, similar to how movement affects spatial awareness in physical interiors.

Thus, the project mirrors principles used in interior architecture education, where VR is increasingly adopted to help students understand space, proportion, volume, and layout (Milovanović et al., 2020).

D. XR Frameworks, Unity Development, and Interaction Toolkits

A growing number of studies analyze XR development frameworks, especially Unity’s XR Interaction Toolkit, which provides modular components to implement VR mechanics without requiring low-level device programming. The toolkit supports grab interactions, raycast pointers, locomotion systems, physics joints, and controller-driven UI interactions—all of which appear in the VR Classroom Interaction project.

Zhang et al. (2021) found that XR Interaction Toolkit significantly reduces development complexity, making it suitable for educational prototypes and rapid design cycles. Likewise, Linowes and Cardoso (2021) emphasize that component-based XR systems accelerate prototyping and reduce time to experimentation.

In the system analyzed here, all major interactions use XR components—such as XR Grab Interactable, XR Simple Interactable, Hinge Joint, and Fixed Joint—as summarized in the user guide’s implementation table (p. 6). This aligns with current trends emphasizing modularity, scalability, and reusability in XR design.

This study contributes to related work by providing a systematic academic analysis of a practical XR Toolkit-based system, showing how modular components combine to form a functional VR classroom environment.

III. SYSTEM OVERVIEW

The VR Classroom Interaction system is developed as a component-based virtual environment that integrates interaction fidelity, interior spatial design, and embodied navigation into a cohesive classroom simulation. Built using Unity’s XR Interaction Toolkit, the system showcases how VR interaction mechanics and interior design principles co-define user experience inside a virtual educational interior. This chapter provides a detailed overview of the system architecture, interaction subsystems, spatial arrangement, and environmental design decisions, drawing directly from the user guide and expanding them into a structured academic interpretation.

A. System Architecture and Design Philosophy

The design of the VR Classroom Interaction system follows two parallel goals:

1. To implement technically reliable VR interaction mechanics, such as grabbing objects, interacting with UI, and operating doors.
2. To simulate an interior layout that mirrors real classroom typologies, emphasizing spatial clarity, ergonomic scale, and functional zoning.

These goals are realized through a modular architecture consisting of:

- Locomotion subsystem (movement + head-bobbing)
- Interaction subsystem (hover, grab, UI)
- Environmental subsystem (door mechanics, object placement)
- Interior spatial layout subsystem (room geometry, circulation paths, functional zones)

Each subsystem contributes to both the *physical* and *perceptual* realism of the VR classroom environment.

B. Spatial Layout and Interior Arrangement

According to the user guide, the virtual environment begins in a school hallway, from which the user enters the first classroom on the right. This reflects interior circulation principles, guiding users through a predictable spatial sequence (corridor → entry → main room) as typically found in real educational buildings.

Inside the classroom, all interactable objects are placed on desks in front of the user when the simulation starts (pp. 3–5) . This spatial decision aligns with interior design practices that emphasize:

- Functional Zoning: Grouping learning materials in a workspace area (desk zone).
- Visual Legibility: Ensuring objects of interest are immediately visible.
- Ergonomic Reach: Placing objects at realistic desk height for natural grabbing.

The overall classroom is arranged with standard educational furniture—desks, chairs, windows, shelving—creating familiar environmental cues that support spatial cognition, an important aspect of VR interior simulations (Milovanović et al., 2020).

C. Locomotion System: Movement and Interior Perception

The locomotion system uses a custom head-bobbing script to simulate natural vertical oscillation during walking (p. 2) . Although simple, this feature significantly affects how users perceive the interior space.

Interior Design Implications:

- Enhances the perception of room proportion and furniture scale.
- Reinforces environmental immersion, making the interior feel occupied and physical.
- Creates a sense of situatedness, allowing users to interpret interior boundaries and volumes as they move.

Thus, the locomotion system contributes not only to

movement fidelity but also to *architectural presence* within the virtual classroom.

D. Direct Object Manipulation System

Six custom-made classroom objects—apple, lunch box, pencil, pencil case, book, and tumbler—are implemented with XR Grab Interactable components, enabling natural pick-up and manipulation behaviors (pp. 3–5) .

Technical Function

- Rigidbody physics simulate natural object weight.
- Attach points align objects with user hand poses.
- Grabbing is initiated via the Primary Button.

Interior Design Relevance

These objects are typical learning tools found on classroom desks. Their inclusion and placement support:

- Contextual realism — objects belong to the interior typology.
- Task-driven interaction — users perform actions similar to real students.
- Embodied exploratory learning — handling items builds environmental familiarity.

This connection between object interaction and spatial authenticity is essential for VR interior simulations.

E. UI Interaction and Spatial Ergonomics

UI interaction is performed using Left Button One on the controller (p. 2) .

Technical Structure

- UI canvases placed in world space
- XR UI Input Module handles button detection
- Interactive elements follow ray-based selection

Interior Design Perspective

The placement and orientation of VR UI panels must respect:

- Sightlines (visibility from typical viewing angles)
- Ergonomic height (aligning with standing or seated eye level)
- Minimal intrusion into the interior space

Thus, even the UI design aligns with interior organization principles affecting comfort and usability.

IV. METHODOLOGY

The development of the VR Classroom Interaction system follows a design-oriented research methodology that integrates VR interaction engineering, interior spatial planning, and user-centered design principles. The methodology is divided into four major phases:

1. Environmental Planning and Interior Spatial Structuring
2. Interaction System Design Using XR Toolkit Components
3. Implementation of Mechanics and Interior Object Placement

This chapter outlines the processes, tools, and decision frameworks used to construct the virtual classroom environment, ensuring that both technical and interior design considerations inform the final system.

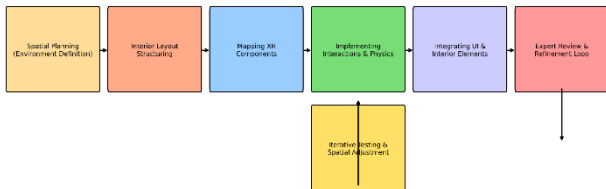


Figure 1. Research Flow

A. Environmental and Interior Spatial Planning

The development process began with establishing the overall spatial structure of the virtual environment. Users spawn in a school hallway and enter the first classroom on the right, as described in the user guide (p. 1). This circulation flow reflects common architectural configurations in educational interiors, supporting intuitive navigation and spatial legibility. Inside the classroom, the layout was planned according to interior design principles such as functional zoning, ergonomic accessibility, and visibility. The six interactable items—apple, lunch box, pencil, pencil case, book, and tumbler—were selected for their relevance to classroom settings and positioned on desks in front of the user (pp. 3–5). Their scaling and placement were carefully aligned with realistic desk height and reach range, ensuring that interactions would mirror physical classroom behavior.

B. Interaction System Design Using XR Toolkit Components

The next stage involved designing the interaction mechanisms by mapping user needs to Unity’s XR Interaction Toolkit. Based on the documented features (pp. 1–7), the system required four primary interaction modes: locomotion, hover feedback, object grabbing, and door manipulation. Each mode was supported through specific XR components. Hover detection used XR Simple Interactable combined with outline shaders to signal affordances. Object manipulation was enabled through XR Grab Interactable, allowing realistic pickup and movement. Door operation was implemented with a hinge joint for rotational behavior and a fixed joint for the door handle. UI interaction used the XR UI Input Module mapped to the Left Button One controller input. This structured mapping ensured that each interaction aligned with VR best practices and was consistent with the spatial characteristics of the classroom interior.

C. Integrated Implementation of Mechanics and Interior Elements

During implementation, technical interaction systems were integrated with interior spatial elements to ensure coherent behavior across the environment. A custom head-bobbing script was added to enhance locomotion realism, reinforcing users’ perception of room scale and proportions (p. 2). Hover outlines were tuned to improve object discoverability without disrupting the visual harmony of the interior. Interactable objects were implemented with rigidbody physics to support natural motion, while door interactions followed architectural behavior through joint-based physics (p. 6). UI panels were placed at eye-level viewing angles so that interface elements blended seamlessly within the classroom rather than obstructing spatial flow. This phase ensured that the technical and interior components functioned cohesively as a unified VR environment.

V. IMPLEMENTATION

The implementation of the VR Classroom Interaction system operationalizes the methodological foundations described in Chapter 4. Built in Unity using the XR Interaction Toolkit, the system translates conceptual interaction models and interior spatial planning into a functional virtual environment. The implementation covers locomotion, affordance signaling, object manipulation, environmental interaction, and user interface systems, each integrated within the spatial and ergonomic constraints of the classroom interior.

A. Environmental and Interior Spatial Construction

The implementation began with translating the planned spatial layout into Unity’s 3D environment. The hallway and classroom spaces described in the user guide (p. 1) were constructed using modular architectural assets and scaled according to standard interior design proportions. The walls, windows, desks, and chairs were positioned to reflect real classroom ergonomics, ensuring that user movement, sightlines, and reach distances were consistent with lived interior experiences.



Figure 2. Head Bobbing While Walking

Furniture models were arranged to support natural circulation: clear walking paths were maintained between rows of desks, and interactable items were placed on the tabletops where students would typically find them. Each object—apple, lunch box, pencil, pencil case, book,

tumbler—was imported, scaled, and positioned according to interior design guidelines regarding functional zoning and ergonomic accessibility (pp. 3–5). This placement ensured that object interaction occurred within a realistic spatial context, reinforcing environmental believability.

Lighting and environmental materials were adjusted to maintain visual coherence. Neutral classroom colors were applied to walls and furniture to avoid distracting the user from interactable items, mimicking typical educational interior palettes. These adjustments contribute to spatial clarity and enhance object visibility during interaction.

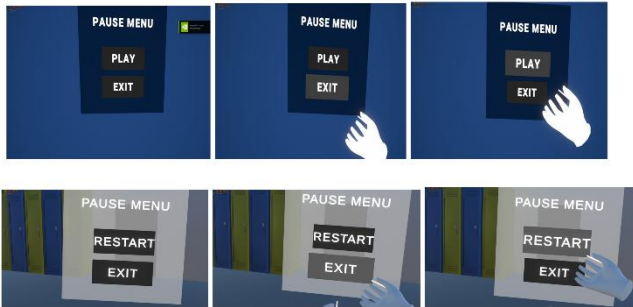


Figure 3. UI Interaction

B. Interaction System Implementation Using XR Toolkit Components

The interaction mechanics were implemented by integrating Unity’s XR Interaction Toolkit components into the interior environment. Each mechanic outlined in the user guide (pp. 1–7) was translated into functional systems using event-driven XR architecture.

Hover interaction was implemented by attaching XR Simple Interactable and outline materials to all interactable objects. The shader settings were calibrated to highlight object edges when the controller hovered over them, providing immediate affordance cues.

Direct grabbing was implemented through XR Grab Interactable. Each classroom item was assigned a Collider, Rigidbody, and customizable attach point to ensure natural picking, holding, and rotation. Physics interpolation and collision layers were fine-tuned to prevent erratic motion in tight interior spaces.

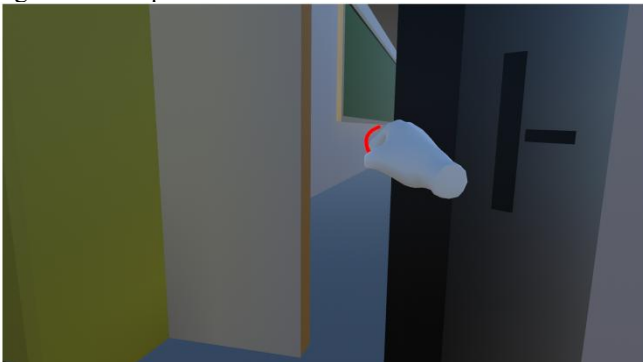


Figure 4. UI Interaction

Door interaction was implemented using two joint components: a Hinge Joint for the door’s rotational behavior and a Fixed Joint to anchor the handle to the door (p. 6). Angular limits in the hinge were adjusted so that the door opened realistically without clipping into adjacent geometry or obstructing movement paths. The handle’s interaction state

was linked to the hinge torque, creating a natural opening motion when grabbed.

Locomotion used the XR Rig along with a custom head-bobbing script (p. 2), introducing a subtle oscillation effect tied to player movement speed. This effect enhanced users’ perception of room scale and reinforced the physicality of navigating a designed interior.

UI interaction was achieved using the XR UI Input Module mapped to the Left Button One input (p. 2). World-space canvases were positioned at eye level and angled slightly forward to ensure that they remained visible and accessible without disrupting interaction flow within the classroom.

C. Integrated Execution of Mechanics Within the Interior Environment

The final implementation phase involved integrating interaction mechanics with the spatial architecture to ensure cohesive and believable behavior across the environment. This integration process required fine adjustments to object placement, collider boundaries, and spatial alignment to prevent interaction conflicts.

For example, object colliders were resized so users could smoothly pick up items without colliding with desk meshes. Desk heights and object placement were adjusted so that grab interactions occurred within comfortable ergonomic ranges. Door swing angles were tested in context to ensure they did not obstruct interior circulation or collide with nearby desks, reflecting architectural realism.



Figure 5. Grabbing Object System

Hover outlines were evaluated within the actual lighting conditions of the classroom to ensure adequate contrast against interior materials. UI panels were strategically positioned to avoid blocking classroom sightlines or appearing unnaturally detached from the environment.

Throughout the integration process, interior design considerations—furniture arrangement, visual hierarchy, circulation patterns, ergonomic proportions—guided the refinement of interaction mechanics. This ensured that the virtual classroom functioned not merely as a technical demo but as a coherent interior environment where interaction behavior aligned naturally with spatial context, reinforcing immersion and user comfort.

VI. CONCLUSION & FUTURE WORK

A. Conclusion

This study analyzed the design and implementation of a VR Classroom Interaction system developed using Unity's XR Interaction Toolkit and structured according to interior design principles. By integrating interaction fidelity with spatial planning, the system successfully demonstrated how VR environments can replicate classroom interiors in a realistic and intuitive manner. Key features—including hover-based affordance cues, object grabbing, door interaction with hinge and fixed joints, and head-bobbing locomotion—were implemented in alignment with the spatial and ergonomic characteristics of the classroom layout described in the user guide (pp. 1–7).

The system highlights the importance of merging interaction design and interior design logic. Object placement on desks enhanced usability by leveraging functional zoning; circulation paths were crafted to reflect real classroom navigation; and UI elements were positioned based on ergonomic considerations. The resulting VR environment achieved coherence between digital mechanics and architectural behavior, supporting a more immersive and believable user experience. These outcomes reinforce findings in existing literature showing that realistic interior spatial structures significantly influence presence, task performance, and spatial cognition in VR environments.

Overall, the project illustrates how VR can serve as an effective medium for exploring educational interiors, supporting embodied learning through direct manipulation and spatial interaction. It also demonstrates how modular XR components can be strategically applied to build rich, interior-accurate simulations.

B. Future Work

Future development of the VR Classroom Interaction system could focus on expanding the spatial scale and complexity of the environment. Introducing additional rooms such as laboratories, libraries, or multipurpose halls would allow the system to support richer interior navigation tasks and provide a broader testbed for studying spatial cognition in educational interiors. This expansion would also enable comparative analysis of how different room functions influence user movement, interaction patterns, and environmental understanding.

Another promising direction lies in enhancing interaction diversity within the classroom. Adding new mechanics—such as writing on boards, opening drawers, rearranging furniture, or interacting with digital learning materials—would deepen the realism of the simulation and support a wider range of pedagogical activities. These improvements would allow the environment to function not only as a VR interaction demo but as a comprehensive educational tool that mirrors the complexity of real-world classroom behaviors.

Finally, systematic user evaluation should be conducted to assess usability, interaction fidelity, and spatial

comprehension. Incorporating feedback from students, educators, interior designers, and VR professionals would provide critical insights into how effectively the system communicates spatial intent and supports natural interaction. Quantitative measures such as task completion time, error rates, and subjective presence ratings would strengthen the validity of the system and guide refinements for future versions.

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