Bridging Theory and Practice: Evaluating a Game-Based VR Approach in Construction Education

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Abstract: Using Virtual Reality (VR) in design education has become a more popular and innovative way to teach. Learning environments that use VR can increase engagement, improve spatial awareness, and create immersive experiences that connect theoretical knowledge with practical application. However, even with these benefits, the usefulness of virtual reality in construction education is still an area that needs to be studied more. This study investigates the process of moving from concept to practice in the development and initial evaluation of a game-based virtual reality application that is intended to help interior architecture students learn the basic concepts of construction. The purpose of the research is to find out how students view the VR game in terms of usability, engagement, and instructional effectiveness, as well as to identify areas that could be improved. Five interior architecture students participated in a pilot study in which they played with the VR game and offered feedback using post-experience surveys and semi-structured interviews. Thematic analysis of responses from participants concluded that the use of VR enhanced interactive learning, spatial understanding, and learner motivation. Yet some limitations were found, namely the need for more explicit guidance in the game, improved readability of text, and clearer navigation flow. These findings are enlightening empirically regarding the actual application of VR in construction education, validating the need for iterative design cycles and user-centered development. The study highlights the role of student feedback in enhancing educational VR tools and offers insights to educators, instructional designers, and developers who are looking to integrate immersive technologies into construction education programs. By examining the educational potential and design limitation of this VR game-based method through analysis, this study aims to enhance the enhancement of interactive learning environments in the interior architecture courses.

Keywords: Virtual reality, Game-Based learning, Construction education, Interior architecture education

1. Introduction

Virtual Reality (VR) has emerged as a pioneering tool in design education, providing experiential learning that is generally unattainable through traditional techniques. It has been widely utilized across various disciplines to enhance students' spatial comprehension, augment engagement, and illustrate practical applications of theoretical concepts. By facilitating user interaction and navigation inside three-dimensional environments, VR allows students to bridge the divide between theory and practice, especially in fields like architecture and design, where spatial intelligence and practical expertise are paramount.

The utilization of VR in the instruction of construction, particularly in interior architecture, is garnering growing interest. Given that interior architecture necessitates both design and technical expertise, virtual reality offers a unique opportunity to enhance the understanding of construction materials, structural systems, and design principles in a way that traditional methods such as drawings or lectures cannot facilitate. Game-based VR applications possess the capacity to engage students actively, offering interactive experiences that allow them to navigate building structures, tactilely interact with materials, and imitate construction processes. Such experiences allow students to acquire theoretical knowledge and apply it in practical contexts, hence enhancing the learning process.

This study aims to assess interior architecture students' perceptions on the usability, engagement, and instructional efficacy of a game-based VR tool. This research seeks to evaluate the experiences of students who employed the VR tool to ascertain the strengths and limitations of the VR game, ultimately determining its potential to enhance construction education. The ultimate goal is to assess if this VR technique effectively bridges theory and practice in building education, providing a more immersive and engaging experience for aspiring interior architects.

Given the small sample and context-specific nature of the study, findings should not be interpreted as generalizable but rather constructed to provide intensive insights into early-stage development and usability of the VR tool. As a qualitative case study, richness of participants' perspectives takes priority over statistical

[1] *This work was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under the 2224-A – Grant Program for Participation in Scientific Meetings Abroad.*

representation. Future research should investigate the long-term impacts of VR-based learning on information retention and its comparison to conventional approaches. Extending the research to encompass a broader and more heterogeneous student demographic might yield more substantial data regarding the VR tool's efficacy across various educational contexts.

2. Method

This study takes a qualitative case study approach to evaluate a game-based virtual reality (VR) application for the improvement of learning basic construction principles among interior architecture students. The research design includes a pilot trial with semi-structured interviews to obtain rich data regarding the usability, user engagement, and teaching effectiveness of the application. Participants' comments were evaluated using thematic analysis to enable the identification of repeated themes and areas of improvement.

2.1 Research Design and Approach

A preliminary research was undertaken to assess the initial iteration of the VR game. Thematic analysis was utilized to understand participant feedback obtained from interviews and surveys. This enabled the researchers to discern patterns, difficulties, and recommendations concerning the VR tool's efficacy in achieving instructional objectives.

2.2 Participants and Data Collection Methods

Although the main study is to be carried out with second-year interior architecture students, the pilot study which is the main topic of this research, was done with five fourth-year students who volunteered to participate. This was selected because they were comparatively higher in their knowledge level regarding construction practices and course materials, which was expected to give more precise and constructive comments in the testing phase. Their prior experience with various aspects of design education well prepared them to critically examine the VR tool and its pedagogical potential. The outcomes of this pilot group were considered worthwhile for refining the tool before implementing it with the target group.

Data was gathered using a semi-structured interviews. Semi-structured interviews let researchers to investigate participants' experiences and feedback comprehensively and gathering data on certain dimensions such as usability, engagement, and instructional efficacy. These dimensions were designed based on the Attitudes toward Virtual Reality Technology Scale (AVRTS) by Bunz, Seibert, and Hendrickse (2021). To measure the attitudes of participants in relation to the VR tool, the items were categorized under three broad dimensions found in the AVRTS model: Ease of Use, Usefulness, and Enjoyment. The Ease of Use dimension assessed how intuitive and user-friendly the VR system was perceived to be; Usefulness evaluated the extent to which the students believed the tool supported the achievement of learning objectives; and Enjoyment evaluated the level of intrinsic motivation and enjoyment obtained from the VR activity. This categorization provided a structured framework for investigating the effectiveness and user acceptance of the VR-based learning tool.

2.3 Development of the VR Game

The VR game utilized in this study was developed as a game-based educational instrument for interior architecture students to investigate and comprehend essential construction materials and procedures. The game seeks to connect theoretical knowledge with practical application, enabling students to engage with virtual construction sites and materials. The program includes features such as 3D modeling of construction components, color-coded walls, interactive jobs, and a navigation system utilizing teleportation. The creation of the VR game involved several software processes and tools aimed at the precise presentation of design as well as complete integration into virtual space. First, precise 2D technical drawings for the construction parts were created through AutoCAD to form a working blueprint for digital models. Then, SketchUp was applied to convert these 2D drawings into 3D models, where more detailed structural pieces, materials, and spatial conditions were created. Finally, the 3D models were imported into Unreal Engine 5.5, where the game environment was built, the interaction was coded, and VR functionality was integrated in a way that provided users with an immersive and interactive learning experience.The primary objectives of the game were to:

- Augmenting students' spatial understanding of construction materials and structures.
- Creating an engaging environment consist of 8 different rooms, that allows students to interact with various construction materials, such as gypsum, brick, reinforced concrete, and Ytong.
- Promoting engagement using game-based learning methodologies while upholding educational integrity.

3. Literature Review

Literature review of this study will concentrate on three primary domains: game-based learning (GBL) in education, the function of virtual reality (VR) in design and construction education, and the obstacles related to the use of VR in educational environments. The discourse on GBL will emphasize its efficacy in enhancing student engagement, motivation, and knowledge retention, especially within technical and design fields. This study will examine the incorporation of VR in construction education regarding its capacity to augment spatial awareness, promote experiential learning, and boost understanding of intricate architectural and structural principles. The limitations of virtual reality in education, including accessibility, usability concerns, cognitive overload, and the necessity for pedagogically robust content, will be addressed. This review will enhance the study by situating the VR-based building learning experience within current research, delineating its possible advantages and drawbacks, and establishing a basis for assessing its practical applicationsin interior architecture education.

3.1 Game-Based Learning in Education

Game-based learning (GBL) is increasingly acknowledged as an excellent educational method that improves student engagement, motivation, and knowledge retention. Research demonstrates that GBL utilizes interactive and immersive experiences to establish significant learning settings, especially in disciplines necessitating complex problem-solving and critical thinking abilities (Gee, 2003). Through the integration of game mechanisms including challenges, rewards, and progression systems, Game-Based Learning (GBL) cultivates intrinsic motivation and prolonged engagement, which are frequently challenging to attain in conventional educational environments (Malone & Lepper, 1987). Prensky (2001) contends that digital game-based learning corresponds effectively with the cognitive and behavioral tendencies of contemporary learners, who are familiar with interactive digital settings. This methodology has been extensively utilized across various fields, such as STEM education, language acquisition, and vocational training, exhibiting notable enhancements in both immediate engagement and sustained information retention.

The utilization of game-based learning in architectural and construction education is increasingly recognized, as it enables students to actively engage with spatial concepts, design principles, and structural problem-solving within a virtual context (Ebner & Holzinger, 2007). Research indicates that incorporating game aspects into virtual reality (VR)-based construction education improves spatial cognition and facilitates experiential learning, hence connecting theoretical knowledge with practical application (Rupp et al., 2019). Moreover, studies indicate that game-based learning (GBL) in virtual reality (VR) environments fosters active engagement and prompt feedback, both essential for skill enhancement in technical and design disciplines (Chang et al., 2017). Notwithstanding these benefits, difficulties persist in reconciling entertainment with educational goals, guaranteeing that the gaming elements enhance rather than detract from learning outcomes (Hamari et al., 2016). As GBL progresses, further research should concentrate on enhancing instructional design, evaluating long-term knowledge retention, and improving adaptive learning systems to tailor experiences for diverse learner profiles.

3.2 Virtual Reality in Design and Construction Education

Virtual Reality (VR) has emerged as a powerful tool in design and construction education, providing immersive, interactive, and experiential learning environments that enhance spatial awareness and practical understanding of architectural and structural concepts. Research has demonstrated that VR enables students to engage with complex spatial relationships and construction techniques that are difficult to grasp through traditional two-dimensional representations (Wojtowicz, 2001). Unlike conventional teaching methods, VR-based learning allows users to experience scaled environments, manipulate digital models, and simulate real-world construction processes, leading to improved comprehension and knowledge retention (Whyte, 2002). Moreover, VR fosters active learning by enabling students to visualize and experiment with structural designs before applying them in real-world scenarios, reducing errors and improving design efficiency (Bouchlaghem et al., 2005). This experiential aspect is particularly beneficial in architectural and construction education, where understanding spatial relationships, material properties, and construction sequences is critical (Sampaio et al., 2010).

The integration of VR into construction education has also been linked to increased student motivation and engagement, as interactive simulations provide a dynamic alternative to traditional classroom-based instruction (Le et al., 2015). Studies indicate that VR-based construction training enhances skill acquisition and safety awareness, offering students a risk-free environment to practice construction techniques and safety protocols (Li et al., 2018). Additionally, VR facilitates collaborative learning, allowing students and professionals to engage in real-time design modifications and problem-solving exercises within shared virtual spaces (Meža et al., 2015). Despite these advantages, challenges remain in terms of accessibility, hardware limitations, and the need for pedagogically sound VR content that aligns with curriculum objectives (Pedro et al., 2020). Future research should focus on optimizing VR applications for construction education by exploring adaptive learning models, improving user interfaces, and assessing long-term learning outcomes in real-world professional contexts.

3.3 Challenges and Limitations of VR in Education

Although Virtual Reality (VR) provides several benefits in education, its deployment entails multiple obstacles and constraints that must be resolved to enhance its efficacy. A primary challenge is accessibility, as virtual reality technology necessitates specialized hardware, such head-mounted displays (HMDs), motion controllers, and high-performance processors, which can be expensive and impose financial obstacles for institutions and students (Radianti et al., 2020). The learning curve of VR interfaces may provide challenges, especially for students unaccustomed to immersive surroundings. Certain studies indicate that although younger students generally acclimate to virtual reality swiftly, others may encounter usability challenges, resulting in frustration and disengagement (Hew & Cheung, 2010). A significant difficulty is the potential for cognitive overload; when learners encounter excessive information or extremely intricate interactions, they may find it difficult to absorb and remember knowledge efficiently (Parong & Mayer, 2018).

4. Data Analysis

This section delineates the principal findings derived from the thematic analysis of participant input collected after VR experience, via semi-structured interviews (Figure 1). The examination concentrates on three primary domains: usability, engagement, and instructional efficacy. Furthermore, prevalent challenges and recommendations for enhancement derived from participant input are encapsulated.

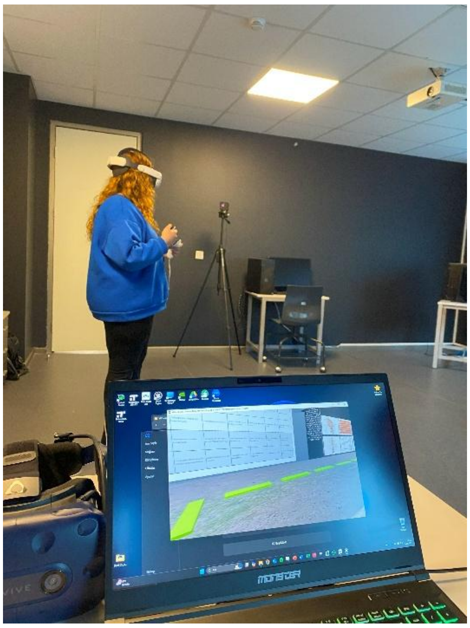

Figure 1: A Participant's experience during the study

4.1 Usability: Ease of Navigation, Interaction with Controls, and User Interface

Participants deemed the VR game user-friendly after acclimating to the controls. The navigation system, especially the teleportation function, was commonly perceived as user-friendly and straightforward. A participant remarked,

P1:"After familiarizing myself with the buttons and their functions, manipulating objects and navigating became rather instinctive." This signifies that the learning curve for utilizing the controls was comparatively brief, allowing participants to acclimate swiftly to the VR environment.

Nevertheless, certain individuals experienced slight difficulties concerning their accuracy in navigating the virtual environment. A participant stated, P2: "I encountered challenges in comfortably attaining my desired position," indicating that while navigation was straightforward, there were intermittent difficulties in establishing precise control over movement. The interface design was largely regarded as clear; nevertheless, some users indicated a requirement for more explicit instructions concerning the movement mechanics, particularly during the initial phase of the experience (Figure 2).

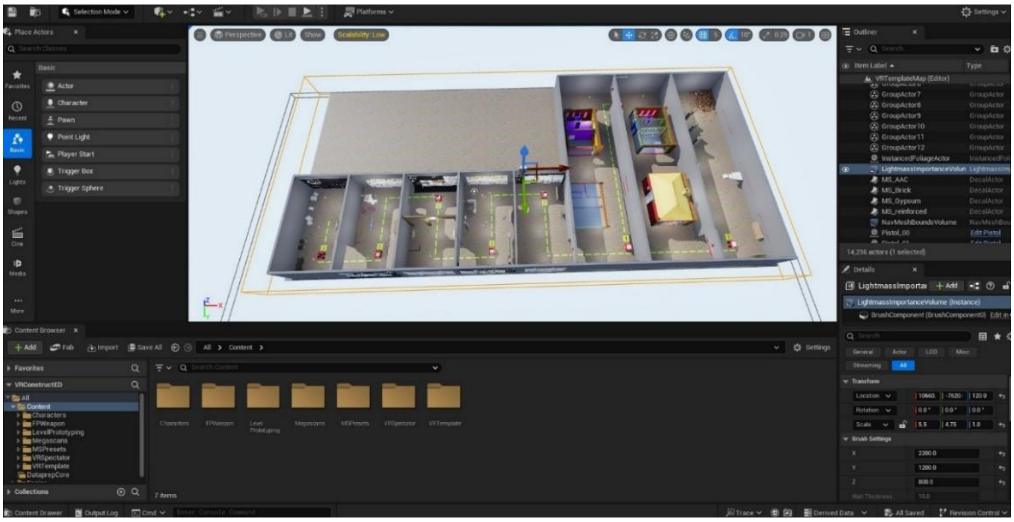

Figure 2: Screenshot from the VR game, Unreal Engine 5.5 editor

4.2 Engagement: Participant Motivation and Level of Immersion in the VR Game

The immersive quality of the VR environment significantly contributed to maintaining participant engagement throughout the encounter. A participant remarked,

P3: "I was fully engaged for the entire duration," emphasizing that the absence of phone access or interruptions facilitated continuous concentration. This demonstrates that the VR game effectively sustained player engagement and reduced external distractions. They also observed that the feeling of immersion improved their educational experience. The capacity to navigate the environment and interact with structural components enhanced engagement significantly. One attendee remarked,

P4: "Experiencing the plan and its elevation at full scale was genuinely impressive and uplifting." This indicates that the VR game successfully cultivated motivation by providing a dynamic and participatory experience that was both informative and pleasurable (Figure 3).

Figure 3: Screenshot from the VR game, Unreal Engine 5.5 editor

4.3 Instructional Effectiveness: Conveying Construction Concepts and Facilitating Learning

The VR game was widely regarded as an efficient medium for communicating construction principles. Participants valued the opportunity to examine materials and construction methods in three dimensions. A participant remarked, P1: "Seeing how each structural element was constructed step by step was highly effective. Then, we examined two different building masses—one in the early construction phase and the other in a fully completed state. This transition process was particularly valuable as it made it easier to understand the different stages of construction." This suggests that the immersive quality of VR significantly improves the comprehension of construction concepts compared to conventional techniques.

Nonetheless, there were apprehensions over the comprehensiveness of the material presented. A participant remarked,

P2: "It requires greater detail, as the current information fails to adequately convey meaning, particularly for those unfamiliar with the topic." (Figure 4). This response indicates that although the VR tool effectively introduced construction materials and concepts, it required more comprehensive explanations, particularly for individuals less acquainted with the area.

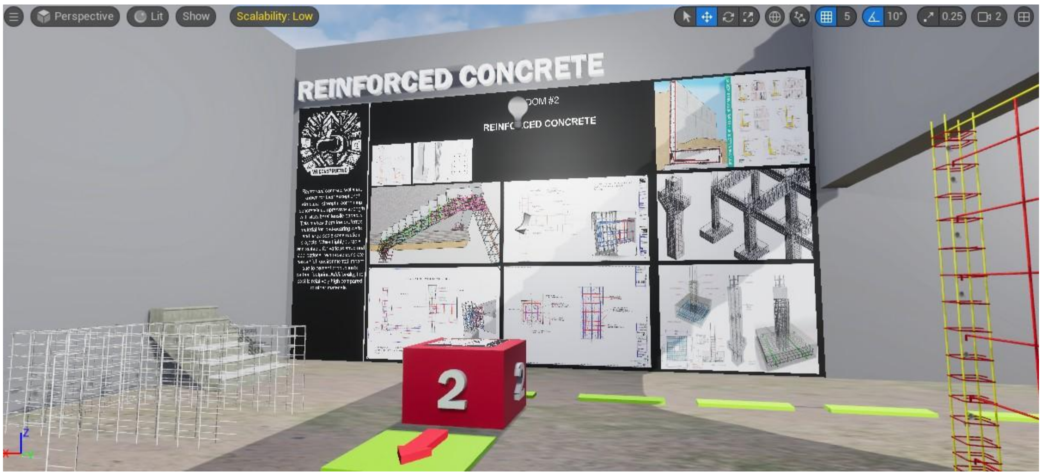

Figure 4: Screenshot from the VR game, Unreal Engine 5.5 editor

4.4 Specific Areas of Improvement Derived from Participant Feedback

There were some development areas that were identified by the participants. They include:

- In-Game Instructions: Players recommended providing more instructions and interactive features throughout the game. For instance, a player recommended, "I think that each room should have clear instructions on what is to be done there." (P3). This indicates that more formal in-game instruction would enable users to comprehend the task and navigate the experience more easily.
- Text Readability: A persistent issue was that text was difficult to read, particularly when seen from a distance. As one user commented, "I had trouble reading the text. This might have added to my eye strain." (P4). Better placement and sizing of text and more readable fonts would enhance the readability of the system and make it more usable.
- Navigation Flow: A few of the participants found the navigation flow confusing, especially where they needed to move from one area of the VR space to another. One participant commented, "I was wondering if there was going to be a final room where I could use the object that I was carrying." (P5). This indicates that a more structured path with more instructions on where to proceed next would enhance the flow of the experience and avoid confusion.
- Interactive Tasks and Material Choice: A number of participants recommended incorporating more interactive tasks to enhance the learning experience. For instance, one participant recommended, "Rather than a quiz at the end, little interactive tests or tasks could be inserted into each room in order to provide ongoing learning." (P1). This would work to keep students engaged throughout the experience and provide more interactive, hands-on learning (Figure 5).
- Material Details: The second key area of improvement was the addition of more information on material details. As one of the users put it, "The game has to include more detail when it comes to materials and use." (P3). Adding more in-depth material regarding the nature, durability, and use of various building materials can enhance the learning potential of the VR tool.

The findings indicate that although the VR game offered significant learning opportunities, there are aspects that require improvement to align the tool with educational goals and enhance the user experience.

Figure 5: Screenshot from the VR game, Unreal Engine 5.5 editor

5. Discussion and Conclusion

This study's findings offer significant insights into the efficacy of a game-based VR strategy in improving construction instruction, especially for interior architecture students. The VR game was created to connect theoretical knowledge with practical application through an immersive learning experience. Participant feedback underscores several critical elements pertinent to this purpose, revealing both the strengths and opportunities for enhancement in the VR tool.

5.1 How Does the VR Game Contribute to Bridging Theory and Practice in Construction Education?

The principal objective of this VR tool was to simulate an environment that accurately reflects real-world construction processes, allowing students to engage with construction materials and techniques in a virtual setting. The game effectively enabled students to envision and manipulate materials like as gypsum, brick, reinforced conrete and Ytong in three-dimensional space, a feat sometimes challenging to accomplish using conventional teaching techniques like textbooks or lectures. This immersive experience facilitated students in establishing concrete connections between theoretical knowledge and practical applications, corroborating previous studies that highlight the capacity of VR to improve spatial understanding and real-world application in design and construction education.

Participants observed that the capacity to examine construction materials at full scale and engage with them in real-time offered a deeper, more significant comprehension of construction processes than conventional teaching approaches. A participant remarked,

P2: "If presented with a construction textbook and the chance to engage with the same content in VR for 20 minutes, I would acquire considerably less knowledge from the book than from the VR experience." This finding supports research demonstrating that immersive VR environments improve learning outcomes by facilitating experiential learning opportunities.

5.2 The Effectiveness of Game-Based VR in Improving Spatial Comprehension and Motivating Students

Game-based virtual reality has demonstrated the enhancement of spatial understanding by allowing students to engage with a constructed environment in three dimensions. The participants in this study indicated that the VR game enabled them to perceive construction details with spatial accuracy, hence improving their capacity to conceptualize and comprehend the construction process. The color-coded walls, three-dimensional representations, and interactive components significantly aided students in comprehending scale and structure, hence enhancing their grasp of construction materials and techniques.

Moreover, the immersive quality of the VR game was important in sustaining student motivation. One participant remarked,

P3: "I was completely engaged throughout the entire duration... I was unable to check my phone, which guaranteed my full immersion in the experience." This supports existing evidence about the beneficial effects of VR's immersive features on student engagement and motivation. By eliminating prevalent distractions and offering an engaging educational setting, VR fosters student concentration and engagement during the learning experience.

5.3 Evaluation of the Usability of the VR Tool: What Worked Well?

The VR game was predominantly acclaimed for its usability. The teleportation system and intuitive interface design were commended for their user-friendliness, enabling students to traverse the virtual environment with minimal exertion. Participants reported feeling immersed and motivated throughout the experience, emphasizing that the interactive elements helped reinforce their understanding of construction concepts. One participant noted that "learning through doing" in the VR setting contributed to greater retention of information. Nonetheless, certain usability issues arose, especially concerning text legibility and interaction accuracy. Participants reported challenges in reading text, especially from a distance, with one individual stating,

P4: "I had difficulty reading the text...this might have contributed to my eye strain." Improving text clarity, font size, and accessibility may enhance the user experience, particularly for students with diverse visual abilities.

Moreover, although the movement and navigation technology was intuitive, certain participants encountered challenges in precisely situating themselves within the VR scene. This problem was particularly evident when trying to engage with specific materials or interact with finer details. The identified usability difficulties indicate that enhancing the user interface and interaction design would augment overall accessibility and user happiness with the VR game.

This study's findings indicate that VR tools can substantially improve the learning experience in construction education by offering an interactive, immersive, and engaging environment for students. Instructional designers can include these VR components into construction education curriculum, especially for elucidating spatially complex concepts such as material qualities, construction processes, and structural design.

To enhance the efficacy of VR technologies in construction education, it is imperative that designers prioritize the development of clear, structured experiences that systematically guide students through the learning process. This entails guaranteeing that in-game advice is readily accessible, offering explicit instructions and engaging exercises to enhance learning, and including real-time feedback systems to assist students in identifying errors and rectifying them.

Furthermore, VR tools need not to supplant conventional learning techniques totally. Participants emphasized that the integration of theoretical knowledge, practical application, and VR-based learning provides a more holistic educational experience. Consequently, VR need to be regar ded as an ancillary instrument that augments, rather than supplants, conventional techniques such as lectures and illustrations.

5.4 Suggestions for Improving the VR Game Based on Student Feedback

The players identified several areas in which they felt there could be improvement within the VR experience, including a demand for more in-game guidance, particularly in the beginning, to help less skilled VR players navigate more easily. Text legibility was another area of concern, as presenting all material information in an easily readable format from a distance with improved font size, well-spaced text positions, and contrasting colors would ensure maximum accessibility. Navigation also had to be improved, and possibilities were to include a more structured process of advancement through color-coded instructions or signs so the learners proceeded in a more automatic manner. More interactive material with entertaining little quizzes or assignment types scattered in between rooms rather than the central final test also came in suggestion for maintaining learner interest as well as reinforcing learned material. They also requested detailed descriptions of building materials, suggesting additional information on the durability of the materials, sound insulation, and how they would be used in various building practices. Immediate feedback on building work was another suggestion, where the users would receive immediate feedback regarding the accuracy of their material positioning, thereby building up their skills in building practice. Designing the spatial structure of the VR environment was also considered significant, as changing room size and configurations could reduce disorientation and maximize focus. Finally, incorporating haptic feedback, e.g., vibrations during the manipulation of materials or tools, was proposed to increase immersion and provide a better three-dimensional understanding of construction procedures.

Iterative design processes and user testing are crucial in developing educational VR instruments. As this example illustrates, continuous testing and evaluation with real users are necessary for determining any problems and making appropriate modifications. Incorporating user feedback in the design process enables developers to make sure that the VR experience is aligned with students' educational needs and maximize its impact. By continuously refining with the help of user feedback, VR tools can be made increasingly intuitive, interactive, and learning-oriented, enabling them to be as effective a learning aid as possible. Overall, though the VR app that has been examined is found to be promising for application in the context of construction education, ongoing development and creation of additional features will enable it to reach its full potential regarding learning. The incorporation of game-based learning and VR into curricula can have the potential to transform interior architecture and construction teaching by enabling students a better, more immersive understanding of the nature of construction concepts.

Ethics Declaration: This study involved voluntary participation from interior architecture students who provided feedback on a VR-based educational tool through semi-structured interviews. All participants were informed about the purpose of the study and gave their consent before taking part. No personal or sensitive data was collected, and responses were anonymized to protect participant privacy. As the study did not involve medical, psychological, or personally sensitive topics, formal ethical approval was not required according to the guidelines of Bahcesehir University. However, all research procedures were conducted in accordance with ethical principles for human subject research, ensuring transparency, confidentiality, and voluntary participation.

AI Declaration: This work utilized OpenAI's ChatGPT as a tool for language translation, content categorization, and topic synthesis. The AI tool facilitated the translation of participant responses from Turkish to English. Furthermore, although the thematic analysis of participant replies was performed manually, the AI technology was utilized to detect commonly referenced concepts and persistent motifs. The AI-generated content was not utilized directly in the final manuscript. It functioned as an initial framework for organizing the debate, pinpointing essential insights, and ensuring coherence in the presentation of participant comments. All interpretations, conclusions, and scholarly contributions were formulated by the authors based on the gathered data and pertinent literature.

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