Virtual Reality as a Supportive Tool for Design Education

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Abstract
Immersive technologies have gained attention in design pedagogy due to their potential as effective tools for teaching and learning. Virtual reality (VR) has been extensively explored in the design discipline for tasks such as interpretation, visualization, and collaboration. However, most applications of VR have focused on replacing traditional teaching content but there is a lack of research on using VR as a supportive teaching tool. This study evaluated the effectiveness of VR as a supportive educational tool in design education. Employing a one-group pretest-posttest experimental design, the study assessed the impact of VR on learning technical and spatial knowledge among 60 sophomore students enrolled in the College of Architecture. The results showed significantly higher posttest scores following the utilization of VR content as a supportive tool supplementing traditional teaching content. This study also gathered participants' perceptions of using VR. The participants rated the quality of the VR content and the ease of use positively, while a few participants reported discomfort related to eye strain.

Keywords
Design education, Virtual Reality, VR technology, Technology integration, Immersive technology

Introduction
Immersive technologies have emerged as a topic of interest in literature related to pedagogy, particularly for their potential in teaching and learning. Since their introduction in the early twenty-first century, these technologies have been tested and applied across various fields, particularly where visualization is essential. In the design discipline, these technologies have been used and studied extensively for various applications. More specifically, virtual reality (VR), which is one such technology has been used for design interpretation and visualization, design collaboration, and design charette development (Ayer et al., 2016; Dalgarno & Lee, 2010; Zhang et al., 2020). While several studies have found VR to be beneficial for learning, other research suggests that it may not offer any significant advantages, leading to mixed perspectives (Beh et al., 2022; Jensen & Konradsen, 2018; Kim et al., 2021; Pedro et al., 2016).

In most cases, VR has been used to replace traditional content delivery (Ayer et al., 2016), substitute in-person field visits (Krakowka, 2012), and replace face-to-face design collaboration (Hong et al., 2016). In most studies, researchers compared learning outcomes between VR and traditional environments. However, many studies lacked proper controls to identify VR as the key factor behind improved learning (Lawson et al., 2024). Consequently, determining VR's true effect on learning has been challenging. In this research, the authors explored VR as a supportive tool to reinforce content taught in traditional environments. Instead of being primary instructional material, VR content can be effective supportive material after complementing the delivery of content in a traditional classroom setting (Olbina & Glick, 2022).

Supportive teaching-learning tools can be defined as additional information presented and stored in a variety of media and formats that assist in reinforcing the concepts to the learners (Mkhasibe et al., 2020).

Few digital tools such as social media, educational robotics, simulations, narrative-rich videos, and digital games have been tested as supportive tools (Kautsar & Sarno, 2019; Nikolopoulou, 2022; Stathopoulou et al., 2019) in early STEM learning, and they have been found to be beneficial. VR's effectiveness as a supportive learning tool in design education has not been investigated. Considering the effectiveness of VR in other domains, it can be expected to be an effective supportive learning tool, especially for fields such as design that heavily rely on spatial understanding.

Further, most studies have focused on the development, implementation, and usability evaluation of VR content but lacked empirical evidence based on experimental evaluation. The purpose of this study was to evaluate the effectiveness of VR as a supportive educational tool, particularly in design education, employing a one-group pretest-posttest experimental design. Given the objective of measuring the impact of VR as a supportive educational tool on students' learning in addition to traditional content delivery, the one-group pretest-posttest approach was deemed suitable for this study.

This study assessed the effectiveness of VR as a supportive educational tool for design education among 60 sophomore students enrolled in the College of Architecture at the University of Oklahoma, USA. Significantly higher posttest scores were observed following the utilization of VR content compared to pretest scores. The VR content was created by the first author of this study to align with the learning objectives of selected courses. Most of the participants positively rated the quality and the ease of use of the VR content, with a few reporting discomforts such as eye strain.

The rest of the document is structured as follows: the subsequent section presents a review of the literature concentrated on immersive learning tools, particularly those utilized in the design disciplines; the subsequent section outlines the methodology utilized in the study; followed by the results of the pretest-posttest and participant surveys, and lastly, the discussion synthesizes the findings and concludes by providing implications and suggestions for future research.

Literature Review

Digital tools and platforms like smartphones, social media, and cloud-based applications have become indispensable components of our daily routines. It is difficult to imagine life without these in the current days. In developed countries, young individuals are utilizing these technologies even before enrolling in university programs. Integrating these technologies into higher education is expected to benefit students (Lai & Hong, 2015), however available literature also points out associated issues with the use of digital media such as distraction during self-study (Ophir et al., 2009). A recent addition to these technologies is immersive environments. With projected market growth soaring, technology companies are making substantial investments in this area (De Regt et al., 2020).

Immersive Environments as Learning Tools

High-fidelity immersive environments allow users to completely immerse in the digital environment, especially using head-mounted displays (HMD). VR headsets completely replace users' natural field of view with a digital image, which creates the perception of being disconnected from actual surroundings and being immersed in the digital environment. Immersive environments have been found to have positive effects on learning (Jensen & Konradsen, 2018). Research indicates that immersive environments positively impact learning, with studies showing virtual environments as the most effective medium, followed by print media, while videos are considered the least effective (Ijaz et al., 2017). Even limited integration of VR through HMDs in classroom instruction had a positive impact on the performance of the students in comparison to those who only received traditional classroom instructions (Ray & Deb, 2016).

Research has demonstrated the effectiveness of VR in education compared to other mediums, particularly in contexts where understanding three-dimensional (3D) objects is essential (Dalgarno & Lee, 2010). For instance, healthcare educators have embraced VR technology for learning human anatomy, with the development of web-based interactive VR tools, which students found more engaging (Huang et al., 2010). These studies underscore the value of VR as both a visualization and learning tool.

Immersive Environment as Learning Tool in Design Education

Design education is traditionally imparted via design studios mainly based on a constructivist approach where educational material is not only lectured but learners have the opportunity to experience it in their own context. It also allows the learners to grasp it at their own speed. Ayer et al. (2016) stated that VR can be an effective tool for pedagogy used in design education. In design education, 3D models, whether digital or physical, are commonly utilized to enhance understanding of spatial characteristics and context. Unlike two-dimensional (2D) photographs, 3D models provide a more immersive visualization experience, although viewing them on a 2D screen may limit the level of immersion.

Alongside the recognized advantages of VR, a few drawbacks have been identified. Rashid and Asghar (2016) found that VR with HMDs was better for spatial awareness, but in-person teaching in a traditional classroom setting was better for memorizing facts. Additionally, Ijaz et al. (2017) noted that virtual environments require more time to learn compared to other mediums. Considering these limitations, instead of replacing the traditional teaching method with VR, it can be used as a supportive tool for design education. While books, prints, and videos serve as traditional supportive materials in design education, Milligan et al. (2018) suggest that textbooks have limited benefits unless learners can engage with them independently. On the other hand, young students spend a large amount of their time watching multimedia and playing video games and don't consider these activities to be boring. Considering both the advantages and limitations of VR and its potential as an effective supportive tool in education, the subsequent section explores VR's applications in learning domains within the field of design education.

Learning domains and immersive environments in AEC

In learning theories, Bloom's Taxonomy is widely recognized as one of the prominent frameworks. As per Bloom's taxonomy learning occurs in three main psychological domains: psychomotor, affective, and cognitive. The psychomotor domain relates to physical skills, the affective domain involves attitude, and the cognitive domain relates to mental skills. Several studies have evaluated the effectiveness of immersive environments as a teaching tool; Table 1 below provides a summary of studies on the effectiveness of VR across different domains of Bloom's Taxonomy for learning.

In the psychomotor domain, Chander et al. (2021) investigated the use of VR to improve postural stability while working at heights, highlighting its potential to mitigate workers' risk habituation. Albeaino et al. (2022) explored VR's effectiveness in enhancing drone navigation skills, reporting that the VR experience was stimulating. In the affective domain, Kim et al. (2021) studied the use of VR to improve vigilante behavior for onsite hazard reduction, finding VR effective in training. Similarly, Yan et al. (2022) examined VR's impact on willingness to participate in safety training, concluding that VR is effective in changing attitudes. In the cognitive domain, Beh et al. (2022) focused on building utility inspection, noting better knowledge gain and retention using VR. Lucas and Gajjar (2022) investigated VR's effectiveness in learning design and construction sequences, highlighting its positive impact on learning outcomes.

Table 1. Studies indicating the effectiveness of VR technology on learning domains per Bloom's taxonomy

Bloom's Psychological Domain for Learning	Literature	Effectiveness tested for learning or improving	Findings
Psychomotor	(Chander et al., 2021)	Postural stability while working at heights	Mitigates workers' risk habituation
	(Albeaino et al., 2022)	Drone navigation skills	The VR experience was found stimulating
Affective	(Kim et al., 2021)	Improving vigilante behavior for onsite hazard reduction	VR is effective in training
	(Yan et al., 2022)	Willingness to participate in safety training	VR is effective in changing the attitude
Cognitive	(Beh et al., 2022)	Building utility inspection	Better knowledge gain and retention by using VR
	(Lucas & Gajjar, 2022)	Construction sequence	The positive effect of learning

Overall, several studies suggest that VR can assist in enhancing learning across different domains of Bloom's Taxonomy, offering immersive and engaging experiences that facilitate knowledge acquisition and skill development in various contexts. It is worth noting that none of the environments in the studies discussed above were high-fidelity.

Research Objectives

Based on the literature review, it was evident that scholars have examined the effectiveness of virtual environments with varying degrees of immersive-ness. However, the existing body of literature does not support replacing the traditional methods of teaching with VR. Therefore, there is potential for VR to serve as a supplementary tool following the initial delivery of knowledge through traditional means. The current body of literature lacks evidence of VR's effectiveness as a supportive tool for design education. This study attempted to address this gap by testing the effectiveness of VR as a supportive tool in design education; the specific objectives are listed below:

Objective 1: How effective are high-fidelity virtual environments as a supportive learning tool for design education?

Objective 2: How do design students perceive the use of virtual reality as a supportive learning tool?

Methodology

The methodology adopted for this study was divided into two phases. The first phase consisted of several steps such as the selection of course topics to be used for the study, understanding the learning objectives of each selected topic, and creating VR content suitable for the identified learning objectives. Unlike previous studies that often created standalone special projects to test the effectiveness of VR, the authors integrated VR into existing courses. To identify suitable topics, the primary author collaborated with instructors teaching various courses in the College of Architecture at the University of Oklahoma, USA, focusing on areas requiring visualization, such as means and methods, and the history of contemporary architecture. The discussions with instructors also facilitated a clear understanding of the learning objectives associated with each topic, guiding the development of the VR models. Figure 1 below provides an overview of the first phase of the research methodology.

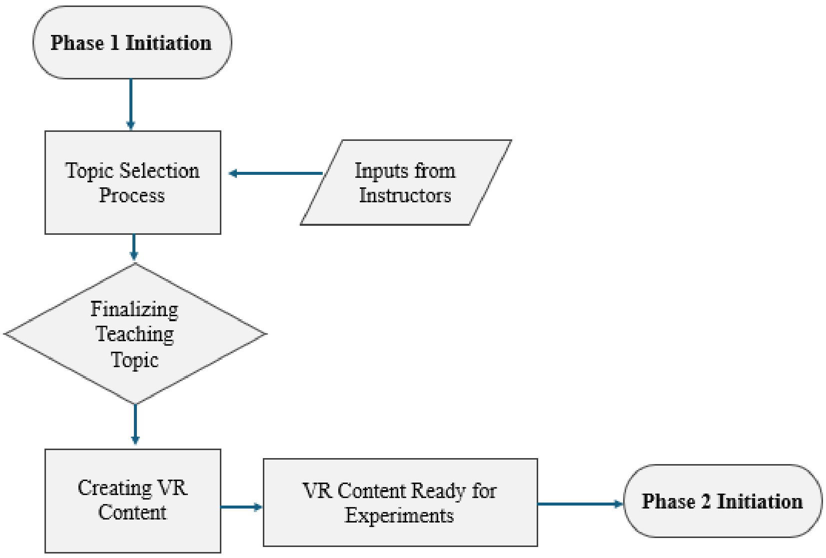

Figure 1. Overview of Phase I of the research methodology.

VR content creation (Phase I)

VR content for the selected courses was created by importing models from software such as SketchUp and Revit to Unreal Engine 5.2 (UE), a robust game design software renowned for creating AAA title games. 3D models created in modeling software such as SketchUp and Revit are not readily compatible with UE. The portability was facilitated with the help of the "Datasmith" plugin. Datasmith was installed in both the exporting and importing software (separate plugins for SketchUp and Revit). During the modeling process, careful attention was paid to segmenting elements and managing complexity to optimize rendering engine performance. Once the model was imported into UE, all the textures, lights, and sounds were added for an immersive experience. The textures from the UE library were used as they have high resolution compared to the textures from the modeling software. After the application of textures, the sound narrations and sound effects were added. All the sounds had adjusted attenuation radiuses to provide information about specific elements in the model. These narrations provided information about the model elements and navigational directions, fostering an immersive experience within the single-level environment, with no movement restrictions or teleportation constraints.

The first environment was created for the means and method course, which included the construction of several types of suspended ceilings (screenshot shown in Figure 2). Students were expected to understand the construction sequence, remember the standard dimensions and terminologies, and remember the different types of acoustic ceilings. This model showed several types of suspended ceilings with and without acoustical ceiling tiles. For a better view, the ceiling grid was lowered and kept at a height of three feet above the finished floor. An informative spot narration was added, and common terminologies and standard dimensions were visible on the walls of the room.

Figure 2. UE interface with environment #1.

The second environment, created for the history of architecture course, was the "Farnsworth House" designed by architect Mies Van Der Rohe. Farnsworth House is well known for its contribution to the modernist movement in architecture (Omneya & Fouad, 2018). From the Farnsworth House model, students were expected to learn about the spatial characteristics of the house, both from the interior and exterior. The Farnsworth House model featured all interior furniture but lacked curtains, deliberately omitted to provide the architect's intended spatial experience for students (screenshot shown in Figure 3). Students could virtually walk around, and inside the house to observe. General information about the designer and architectural style was delivered in a narration. Ambient sounds such as the crackling sound of the fireplace were added for a realistic experience. Throughout both virtual environments, students had the freedom to explore the surroundings at their own pace, walking or teleporting, thus understanding the true scale of the spaces.

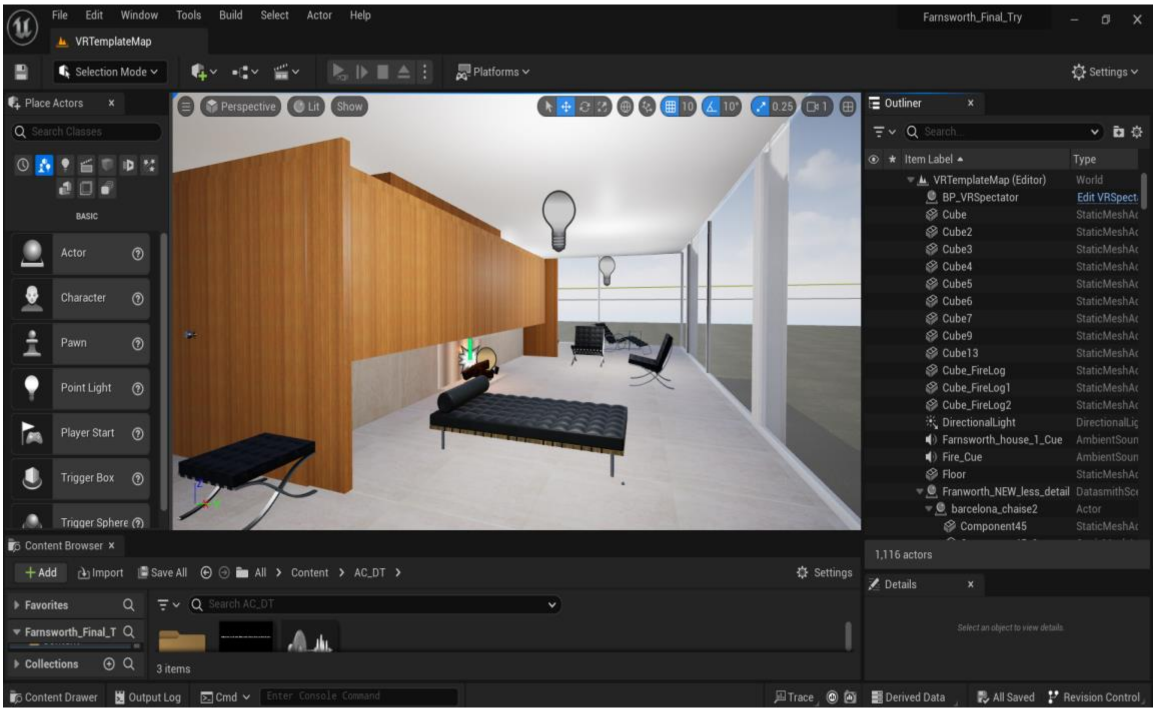

Figure 3. UE interface with environment #2.

Experiment (Phase II)

Phase II of the methodology included the recruitment of participants, setting up the experiment, and conducting the perception survey; the following section provides details of the steps undertaken.

Sample Selection

For this study, undergraduate students at the sophomore level were recruited from the College of Architecture at the University of Oklahoma, USA. When using Soper's (2020) A-priory sample calculator, with an effect size of 0.7, a statistical power level of 0.8, and a probability level of 0.05, the minimum required sample size is 68. Additionally, considering the undergraduate student population in the design disciplines at the College of Architecture to be 350, with a confidence interval of 95% and a margin of error of 10%, the required sample size was 76. A total of 115 students were invited, and 60 students agreed to participate in the study, falling short of the required sample size. A post-hoc calculation of the margin of error for the 60 responses resulted in a margin of error higher than the initially considered 10% for sample size estimation. This margin was deemed acceptable for this study since no inferential statistics were used to generalize the results.

Experiment Design

For this study, a one-group pretest-posttest design was adopted. In this experimental design, the dependent variable was measured before and after the treatment to measure the effect. If the average posttest score is better than the average pretest score, then it can be concluded that the treatment might be responsible for the improvement. Despite the inherent limitation, the authors chose the one-group pretest-posttest design for two reasons: firstly, the study aimed to explore VR's impact as a supportive educational tool rather than being the primary content; secondly, integrating VR into existing courses made it impractical to create a control group that would be deprived of the access to VR.

Participants learned the selected topics in a traditional classroom environment as per the class schedule. After the traditional lecture-based learning, the participants completed the pretest questionnaire, which was designed to capture the participants' understanding based on the traditional educational delivery. During the pretest, participants were not allowed to consult any course materials. The purpose of the test was to assess their understanding of the subject matter and their readiness to work on subsequent assignments that required this foundational knowledge. After a week from the pretest, the participants used the virtual environments as supportive educational tools. Participants accessed the VR content for 10 minutes using Meta Quest 2. Participants were able to walk a few steps, rotate, and look around 360 degrees freely. After accessing the VR content, the posttest was conducted. Along with posttest questions, perceptions of participants about the VR environment were recorded using a separate questionnaire. Figure 4 below depicts the overall research methodology adopted in this study.

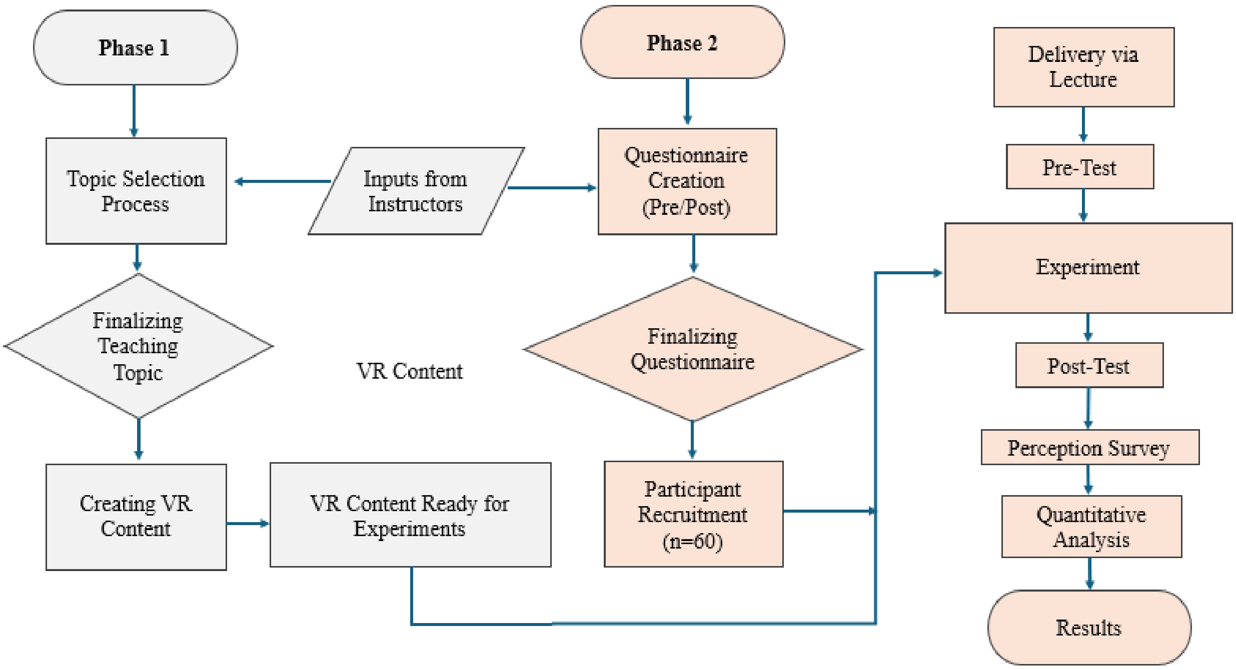

Figure 4. Flowchart depicting the research methodology.

Test instrument:

The pre-test and post-test instruments were designed to assess various aspects of the topical content. For the content on interior ceiling construction, the first question evaluated students' knowledge of the major classification of ceiling systems. The second question focused on recalling technical terminologies by asking for the technical names of the spaces above the suspended ceiling. The third question required students to identify three key components of a suspended ceiling system. The fourth question tested their ability to arrange these components in the correct construction sequence. Finally, the fifth question assessed their retention of technical specifications by asking for the maximum allowable spacing between ceiling hangers.

For the second environment, students were asked the following true or false questions: (1) Do all interior walls of the Farnsworth House touch the ceiling? (2) Is there one flight of stairs to the main floor? (3) Does the Farnsworth House have a fireplace? These questions aimed to assess the student's observational skills regarding key architectural elements, as images of both the interior and exterior of the house were shown in lecture slides. In contrast, the final two questions were designed to assess spatial perception. Students were asked if they felt the house provided a sense of protection and if it appeared stable, heavy, and firmly attached to the ground. This line of questioning followed a class discussion comparing the Farnsworth House with Adolf Loos's Steiner House, where the lack of comfort and security in the Farnsworth House was highlighted.

Results & Analysis

Pretest and posttest data were collected from the participants (n=60) who engaged with VR content as a supportive educational tool. Statistical analysis was conducted using SPSS software. Descriptive statistics including mean and standard deviation were calculated; the average of the pretest scores was 2.37 out of 5 (standard deviation = 0.91, median = 2) and the average of the posttest scores was 3.51 out of 5 (standard deviation = 1.35, median =4). The students completed the pretest immediately after the topics were introduced in the lectures. They could access the VR content as supplementary material before taking the posttests. Both the pretests and posttests were evaluated by the respective course instructors to ensure that the questions aligned with the topics covered in lectures. Table 2 below presents the distribution of scores among the students who participated in the experiment. The results indicate a significant increase in the number of students achieving 90% or higher on the posttest compared to the pretest. Additionally, the proportion of students scoring below 60% decreased considerably in the posttest compared to the pretest.

Table 2. Comparison of students' scores in pretest and posttest

Students' Score	Pretest Number of Students (%)	Posttest Number of Students (%)
≥ 90%	0	18 (29%)
80% - 89%	7 (11%)	17 (28%)
70% - 79%	0	0
60% - 69%	19 (31%)	12 (20%)
≤ 60%	34 (57%)	13 (22%)

A paired sample t-test was performed to determine the significance of improvement in post-test scores compared to pretest scores. Paired sample t-test showed a significant improvement in posttest scores compared to pretest scores [t(60)=6.211, p<.001]. Refer to Table 3.

Table 3. Results of paired sample t-test

Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Significance p
			Lower	Upper			
1.143	1.09	.184	.769	1.517	6.211	59	<.001

Responses of the participants to the survey about the use of VR were analyzed to check for any correlation with their performances. A non-significant positive correlation was found between motivation to use VR and improvement in performance.

Perceptions of the Participants on the Use of VR

The participants were surveyed to assess their perceptions regarding satisfaction and discomfort associated with VR usage. Perception was measured through four questions, covering aspects such as familiarity with VR, level of immersion, attitude towards VR usage, and discomfort experienced during VR use (Appendix I). Out of 60 participants, 14 (23%) had no prior exposure to VR, while 25 (41.6%) had used it once, and 3 participants (5%) indicated regular weekly VR usage. None of the participants reported daily VR engagement. Regarding attitudes towards VR usage, more than half of the respondents (53%) expressed excitement about utilizing VR technology. In response to the question regarding the perceived value of VR content, 17 participants (28%) affirmed its value-addition, with another 18 respondents (20%) expressing curiosity about the technology's potential. No participant mentioned rushing through the activity or finding it boring. Very few of the participants (11%) reported experiencing dizziness and discomfort while using VR, highlighting potential concerns regarding the adverse effects associated with prolonged VR usage. Table 4 below summarizes the responses of the participants regarding ease of use, clarity of the VR environment, strain on eyes, dizziness, and any facial discomfort.

Table 4. Summary of Responses (Scale 1 = min, 5 = max.)

N=60	**Ease of Use**	**Clarity & Quality**	**Strain on Eyes**	**Dizziness**	**Facial Discomfort**
Mean (SD)	4.25 (1.84)	4.46 (0.78)	2.13 (1.25)	2.00 (1.26)	2.41 (1.28)
Median	4	5	2	2	2
Mode	5	5	1	1	2

Discussion

The objective of this study was to explore whether VR fits into the role of being a supportive tool in design education, especially for topics requiring 3D visualization or special understanding of buildings and building elements. Digital technology-friendly students and the prevalence of advanced HMDs at an accessible price have created a conducive environment for integrating immersive technologies in education. While most prior studies have assessed the effectiveness of VR as a substitute for conventional teaching, its potential as a supportive educational tool remains largely unexplored. Design education typically relies on traditional supportive tools such as books, drawings, notes, and diagrams. This gap in the current literature prompted the need to examine the efficacy of VR as a supportive tool in enhancing design education.

A pretest-posttest experiment was used to measure the effect of VR on participants' improvement in learning both spatial and technical knowledge. Participants in the study received instruction on both topics through conventional methods, including slide presentations featuring text, drawings, and photographs. While instructors did not integrate VR into their teaching methods, participants were provided with VR materials as supplementary resources. The improvement in the posttest scores (average of 3.51 out of 5 compared to 2.37 out of 5 in the pretest) could be largely due to the use of VR supplemental content. The improvement in test scores aligns with previous studies highlighting the benefits of immersive environments in design education that involve viewing 3D content, and VR has been claimed as a better way of learning 3D content based on visual memory (Schurgin, 2018; Lindner et al., 2009). The results of this study demonstrate the impact of supplemental materials delivered through VR. While the findings suggest that VR contributed positively, the exact extent of its effect cannot be definitively determined due to the absence of a control group in the pretest-posttest experimental design.

Previous studies have indicated VR's efficacy across various domains of Bloom's taxonomy (Chander et al., 2021; Albeaino et al., 2022; Kim et al., 2021; Lucas & Gajjar, 2022). The finding of this study provides additional evidence of VR's effectiveness not only in enhancing spatial comprehension but also in learning and retaining technical knowledge pertinent to construction, including the sequencing of construction processes, terminology, and dimensional aspects. Furthermore, visuospatial memory, as posited by Lindner, Blosser, and Cunigan (2009), emerges as a pivotal cognitive mechanism over visual memory alone. This suggests that the integration of VR technology not only enhances learners' understanding but also promotes deeper retention of learned concepts compared to traditional methods of teaching relying solely on visual or auditory stimuli.

This study also gathered participants' perceptions of using VR. The user experience of a virtual environment is dependent on the quality of telepresence, ease of use, and discomfort faced by the users (Kim et al., 2021). The participants rated the quality of the VR content and the ease of use positively. Discomfort, mainly eye strain was mentioned by a few participants. For this study, the participants were viewing the VR content for around 10 minutes only. Instructors need to be mindful of the discomfort to the eyes as it can aggravate if the students are expected to view the content for a longer duration. On the other hand, much more complex information can be imparted through VR content in considerably less time than other supportive material such as books, prints, and videos. The use of visuospatial stimuli and motivation to use the VR content can be the responsible factors for this improved effectiveness. During experiments, participants who had used the VR headsets previously were found to be more confident in using the technology, and they also explored the VR content for a longer time. This infers that familiarity doesn't lower the motivation to use the technology.

Though the VR content was found to be effective and the technology easy to use, there are several challenges. Firstly, VR seems useful for topics where spatial and 3D understanding is required, which limits its application. Secondly, VR shows content on a real scale, which means viewers view content in perspective. For a few complex topics, drawings such as isometric and axonometric are used because they simplify the perspective and help to understand the dimensional scale better. This makes it inevitable to use other supportive materials or to include technical drawings, such as isometric, in VR content. In addition, the VR content creation process is time-consuming making it challenging for instructors to create VR content by themselves. Also, if the content is not created by a professional, it becomes difficult to handle the graphics by the HMD without the help of a computer with a graphics processing unit (GPU). For this study, the VR content was created and projected using a laptop with 12th generation i7 with RTX3070 GPU (6 GB). Even with this configuration, the laptop's temperature rose to 95 degrees Celsius after using the VR content for 20-30 minutes. However, none of these challenges seem impossible to overcome.

Conclusion

This research explored the pedagogical value of using immersive technology as a supportive learning tool for architectural educational content. To understand its effectiveness, two learning environments focusing on two different topics were developed. After testing it with 60 students several noteworthy conclusions were drawn. Analysis of pretest and post-test data suggested that VR is effective as a supportive learning tool for architectural educational content. Students showed improvement in retaining technical information after using VR, this information includes the sequence of construction, trade-specific terminologies, standard dimensions, and names of the construction materials. The perception survey expressed minimal issues with discomfort, mainly strain on the eye, during the use of VR. A positive correlation between motivation to use VR and improvement on post-test reveals one of the reasons for the effectiveness of VR as a supportive tool. Overall, motivation to use VR helped in better observation prompting improved knowledge gaining. This is in line with the findings of the literature review, where VR is found to be beneficial in two main learning domains of Bloom's Taxonomy. Overall, this study contributes by addressing a gap in current literature by testing the effectiveness of immersive technologies as a supportive tool in education, particularly in the field of design. The results suggest that VR has the potential to enhance learning outcomes and student engagement. Future research could explore additional factors influencing the effectiveness of VR, such as different pedagogical approaches in the design of VR environments and interactivity levels. Additionally, further investigation into user comfort and VR content creation techniques will be essential for the implementation of VR as a supportive tool in education.

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Appendix I

Q: How familiar are you with virtual reality (VR)?
Never used it
Used it once
Used it several times
Use it every week
Use it every day

Q: Answer the following questions related to the level of immersion in the VR environment on a scale of 1 to 5 (1 = minimum, 5 = maximum)

Items	**1**	**2**	**3**	**4**	**5**
How clearly could you visualize the building elements?					
How real was the feeling of being in the space?					

Q: Rate your experience of using the VR environment on a scale of 1 to 5 (1 = minimum, 5 = maximum)

Items	**1**	**2**	**3**	**4**	**5**
Ease of navigation in the VR environment					
Visual clarity and rendering quality of the VR environment					

Q: Rate your experience related to discomfort while using the VR environment on a scale of 1 to 5 (1 = minimum, 5 = maximum)

Items	**1**	**2**	**3**	**4**	**5**
Strain felt on your eyes when in the VR environment					
Dizziness felt during navigating the VR environment					
Discomfort on your face when using the headset to navigate the VR environment					