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INTEGRATING VIRTUAL REALITY TECHNOLOGY AS A PEDAGOGICAL TOOL IN ARCHITECTURAL EDUCATION: A QUASI-EXPERIMENTAL STUDY

Bushra Obeidat[1*], Intisar Ameen Tyne[2] and Maryam Sameer Haneyah[3]

[1]Jordan University of Science and Technology, Jordan. Email: bbobeidat@just.edu.jo, Orcid: https://orcid.org/0000-0002-7233-0733
[2]Texas State University, Texas. Email: nas167@txstate.edu Orcid: https://orcid.org/0000-0002-2209-6723
[3]Wadi Seer Training College, Educational Facility–UNRWA, Amman, Jordan. Email:mariamsameer1993@outlook.com, Orcid: https://orcid.org/0000-0001-9820-7963

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Corresponding Author: Bushra Obeidat (bbobeidat@just.edu.jo)

ABSTRACT

Virtual Reality (VR) is developing as a viable instrument in architecture education; yet, its utilisation in theoretical and culturally integrated courses is still inadequately investigated. This study examines the effects of immersive VR-based instruction on student learning and satisfaction within a Local Architecture program, utilizing the Raghadan Tourist Terminal in Amman as a case study. Forty-two undergraduate architecture students were randomly allocated to either a virtual reality group or a control group receiving conventional lecture-based training ($n = 21$ per group). The evaluation of knowledge acquisition was conducted using a 12-item assessment based on Bloom's taxonomy, standardised on a 10-point scale, and administered before to and following teaching. Post-test results demonstrated a notable enhancement in both groups (VR: $Z = -3.83$, $p < 0.001$; Control: $Z = -3.62$, $p < 0.001$), with the VR group attaining a superior mean score (8.20 ± 0.92) relative to the control group (6.92 ± 0.83). Domain-level analysis indicated the most significant effect in the "Applying" domain, with the VR group surpassing the control group (1.87 vs. 1.19). Student satisfaction scores corroborated the efficacy of the VR approach: 85.7% concurred that VR improved conceptual visualization, while 81% indicated heightened engagement with the subject matter. Nonetheless, diminished scores were noted in emotional resonance (mean = 3.10 ± 0.79), signifying constraints in the authenticity of the simulated setting. The findings indicate that virtual reality can substantially improve cognitive and motivational results in architectural education, especially in content that is spatially and contextually rich. Additional investigation is required to assess its enduring effects and emotional resonance in depicting architectural heritage.

KEYWORDS: Virtual Reality, Architectural Education, Local Architecture, Immersive Learning, Student Engagement, Bloom's Taxonomy.

1. INTRODUCTION

The swift advancement of digital technologies in the last twenty years has significantly altered the realm of higher education. Educational institutions worldwide have progressively embraced digital tools and platforms to improve learning outcomes, facilitate flexible education, and address the requirements of various student populations. These innovations spanning blended learning environments, interactive courseware, and fully online degree programs have transformed the paradigm of teaching and learning from passive content delivery to more personalised, technology-mediated engagement (Freeman et al., 2014; Radianti et al., 2020).

In the context of digital transformation, immersive technologies have surfaced as notably effective instructional instruments (Radianti et al., 2020). Virtual Reality (VR) is distinguished by its capacity to generate interactive, multimodal worlds that replicate real-world experiences. Virtual reality (VR) is characterised as a computer-generated three-dimensional environment that users may navigate and engage with in real time (Gigante, 1993). Its educational promise resides in its ability to visualise abstract or inaccessible knowledge, model dynamic systems, and immerse learners in immersive environments. These advantages have resulted in its expanding application across multiple disciplines, including medicine, engineering, aviation, and progressively, architectural education (Baniasadi et al., 2020; di Lanzo et al., 2020; Erkan, 2020; Soliman et al., 2021).

Architecture is inherently a spatial discipline that is enhanced by technologies that facilitate visual and experiential comprehension (Obeidat & Jaradat, 2022; Ummihusna & Zairul, 2022). Traditional architectural training has predominantly depended on lectures, slides, and printed drawings; nevertheless, these approaches frequently inadequately communicate the intricacies of architectural forms, spatial perceptions and relationships, and cultural symbolism especially in theory-oriented courses. The difficulty is particularly evident in subjects like architectural history, urban morphology, and vernacular architecture, where students are required to conceptualise environments they may never experience in person (Ibrahim et al., 2021; Shanti & Al-Tarazi, 2023; Shareef & Farivarsadri, 2020).

Virtual Reality presents a viable solution to this deficiency. Virtual reality immerses pupils in realistic, navigable worlds, facilitating a profound understanding of architectural space, structure, and context. In studio-based design education, virtual reality has been utilised to visualise architectural forms, investigate spatial configurations, and improve project presentations (Abdelhameed, 2013; Hajirasouli et al., 2023; Kharvari & Kaiser, 2022). Nonetheless, its capabilities extend beyond design visualisation. The incorporation of VR into theoretical education, especially in culturally significant subjects such as local architecture, creates new opportunities for experiential learning.

Local architecture, sometimes linked to vernacular architecture, pertains to region-specific construction methods influenced by natural factors, historical traditions, and cultural standards (Lozar & Rapoport, 1970). Instructing this subject involves more than mere factual knowledge; it demands contextual interpretation, an appreciation of symbolic elements, and comprehension of spatial logic and material utilisation. Traditional methods, restricted to two-dimensional graphics and written descriptions, fail to adequately represent these complexities. Conversely, immersive VR settings can replicate and showcase culturally significant edifices, enabling students to study, analyse, and experience local architectural features as though they were physically present.

This educational opportunity corresponds with multiple learning theories. Constructivist learning theory, as defined by Piaget (2003) and Vygotsky (1980), underscores the learner's active participation in knowledge construction through significant experiences and social engagement. Virtual reality offers experiences by immersing students in interactive digital environments where they can investigate spatial structures, change visual elements, and obtain instantaneous feedback. Mayer's cognitive theory of multimedia learning posits that learners achieve superior performance when content is presented through both visual and audio modalities. Virtual reality inherently fulfils these criteria by stimulating numerous senses and providing complex information processing (Mayer, 2009). Besides augmenting cognitive comprehension, VR fosters student motivation and emotional involvement (Huang et al., 2020). Keller's ARCS model (1987) posits that four components Attention, Relevance, Confidence, and Satisfaction are crucial for learner motivation (Keller, 1987). Virtual reality addresses these components by offering innovative, pertinent, and immersive experiences that enhance engagement, foster learner confidence through inquiry, and yield satisfaction through active involvement (Allcoat & von Mühlenen, 2018; Coban et al., 2022; Huang et al., 2020).

From an educational approach standpoint, virtual reality facilitates a transition from teachercentered to student-centered learning (Krokos et al., 2018). Conventional architecture education frequently prioritises teacher-directed content dissemination. Conversely, VR promotes student autonomy and active learning via exploration, inquiry, and problem-solving (Chen & Chu, 2024). When employed for site study, historical interpretation, and cultural appraisal, virtual reality enhances cognitive engagement, advancing students through Bloom's taxonomy from mere recall to higher-order thinking, including analysis, evaluation, and creativity (Maghool et al., 2018).

The academic literature progressively demonstrates the efficacy of virtual reality in architecture. Research indicates that virtual reality improves students' spatial awareness, conceptual understanding, and participation in design studios (Abdelhameed, 2013; Erkan, 2020; Gomez-Tone et al., 2022). Prior studies have broadened the applicability of virtual reality to design, building, and historical education. Sampaio and Santos (2011) utilised virtual reality to model the sequencing of the construction process, whereas Bashabsheh et al. (2019) illustrated its effectiveness in instructing building construction courses. Ibrahim et al. (2021) employed VR for case studies in Modern Architecture, while Kowalski et al. (2020) discovered that VR improved students' logical thinking and understanding of architectural principles. Nevertheless, the application of virtual reality in theoretical courses, especially within the realm of local architecture education, is still constrained. Researchers like Bhaumik et al. (2023) and Vicente et al. (2022) call for transcending mere descriptive documenting of vernacular architecture in favour of critical analysis and new visualisation techniques. This shift necessitates instructional tools that connect theory with practice, enabling students to engage with architecture in a substantive manner. Virtual reality, as an immersive medium, possesses the capacity to facilitate this shift. This study examines the efficacy of VR-assisted instruction in a Local Architecture course. The study assesses the efficacy of immersive learning in enhancing students' comprehension of architectural heritage and spatial organisation relative to traditional pedagogical approaches. **The study specifically evaluates**

- Students' knowledge acquisition based on pre- and post-tests structured around Bloom's taxonomy.
- Their satisfaction and engagement levels, measured through a Likert-scale survey.

This work enhances the ongoing discourse on immersive learning technologies in architecture by analysing both cognitive and affective consequences. It further advances the overarching educational objective of amalgamating regionally relevant information with modern digital techniques, so enhancing architectural pedagogy using tools that are culturally significant and pedagogically efficient.

2. METHODOLOGY

This study utilised a quasi-experimental design with a pre-test/post-test control group format to assess the efficacy of virtual reality (VR) as an instructional tool for teaching local architecture. The design was to assess variations in students' knowledge acquisition and satisfaction levels between immersive VR-based learning and traditional lecture-based teaching.

2.1. Participants and Sampling

Forty-two undergraduate architecture students participated in the study. Participants were chosen from two successive academic semesters due to restricted enrolment capacity, assuring uniformity in instructional delivery, course content, and assessment standards. All individuals possessed similar academic backgrounds and lacked prior exposure to the VR content employed in the study.

To strengthen internal validity, participants were randomly assigned to one of two instructional groups

- An experimental group receiving immersive VR-based instruction
- A control group receiving conventional lecture based instruction

2.2. Ethical Considerations

All participants were thoroughly apprised of the study's aims, methodologies, and voluntary participation. Informed consent was acquired from each participant, who maintained the ability to withdraw at any moment without repercussions. No financial or material remuneration was offered. Data confidentiality and anonymity were rigorously upheld, with all information utilised exclusively for academic purposes.

2.3. Instructional Content and Virtual Environment

The instructional content originated from a curriculum on locally conceived public architecture, highlighting local design principles, spatial organisation, and materiality within the Jordanian setting. The chosen case study is the Raghadan Tourist Terminal, an important public structure in central Amman that embodies essential aspects of local architectural identity. Learning materials were created in conjunction with the course teacher to ensure alignment with the course's targeted learning outcomes. **The educational material concentrated on**

- Use of regional materials such as Jordanian white stone.
- Traditional spatial arrangements including porticoes (covered walkways supported by columns) and internal courtyards (open-air spaces enclosed within buildings).
- Local aesthetic features such as mashrabiyas (wooden screens), arches, and rhythmic façade composition (repetitive design patterns).

2.4. Case Study: Raghadan Tourist Terminal

The Ragadan Terminal was initially built in the early 1970s as a significant transit centre linking Amman to other cities, including Zarqa and Al-Russeifa. In 2005, the terminal saw significant redevelopment with assistance from the Japan International Cooperation Agency (JICA), converting it into a modern facility that accommodates both transportation and tourism purposes (Municipality, 2006). The terminal, redesigned by architects Ayman Zuaiter and Khaled Jadallah, amalgamates traditional and contemporary aspects, use locally produced materials including concrete and stone. The architectural methodology, termed "urban stitching" by the designers, integrates the terminal with the adjacent urban environment, enhancing the architectural lexicon of Amman (Consultants, 2006). Its architectural importance evident in scale, materials, spatial organisation, and cultural symbolism makes it an exemplary case study for educational purposes. Figure 1 displays the floor plan of the building, accompanied by photographs of the front and rear elevations. A digital representation of the terminal was created utilising AutoCAD, Revit, and Lumion. The model facilitated immersive navigation of interior and external spaces, allowing students to examine material finishes and investigate architectural sequencing and spatial linkages within an interactive 3D environment. Figure 2 displays rendered perspectives of the VR model utilised during the instructional session. Students in the VR group had structured training sessions on utilising the Oculus Rift S headsets, headphones, and 3D navigation tools to facilitate optimal interaction. Figure 3 illustrates the virtual reality teaching configuration.

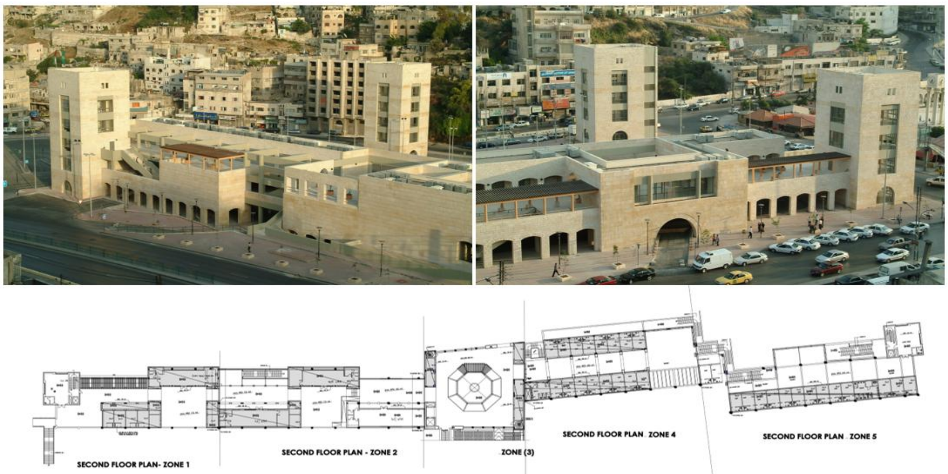

Figure 1: Architectural Floor Plan and Elevation Views of the Raghadan Tourist Terminal, Source: (Consultants, 2006).

Figure 2A: Rendered Model of the RaghadanTerminal for the VR Experiment.

Figure 2B: Rendered Views of the Raghadan Terminal VR Model.

Figure 3: VR-Based Instructional Setup Using Oculus Rift S.

2.5. Assessment Tools

Two assessment methods were utilised knowledge evaluations and a satisfaction survey.

Assessment of Knowledge (Pre- and Post-Assessment).

A 12-item assessment grounded in Bloom's Taxonomy (Bloom et al., 1956) was delivered to both groups prior to and following teaching to assess cognitive advancements. **The examination had multiple-choice and short-answer enquiries pertaining to:**

- Remembering and understanding local architectural elements.
- Applying and analyzing design principles.
- Evaluating spatial qualities and cultural relevance.

The identical test was employed for both pre- and post-assessments, conducted with a 7-day delay between sessions to mitigate recall bias while documenting learning advancements. The sequence of the questions was randomised in the post-test.

2.6. Satisfaction Questionnaire

Subsequent to the VR session, participants in the experimental group filled out an 11-item Likert-scale questionnaire (1 = strongly disagree to 5 = strongly agree) evaluating essential aspects of learning efficacy, encompassing conceptual clarity, engagement, motivation, retention, cognitive stimulation, and overall satisfaction with the educational experience.

Experimental Procedure.

The experiment proceeded through the following stages (see Figure 4 for timeline visualization):

1. **Pre-Test Administration:** Both groups completed the knowledge test to establish a baseline and ensure equivalence.
2. **Instructional Phase**
   - **Control group:** Received a traditional lecture and slideshow presentation led by the course instructor (Figure 5A).
   - **Experimental group:** Engaged individually with the VR simulation using Oculus Rift headsets (Figure 5B) due to hardware constraints.
3. **Post-Test and Survey:** Both groups completed the post-test. The VR group also filled out the satisfaction survey.

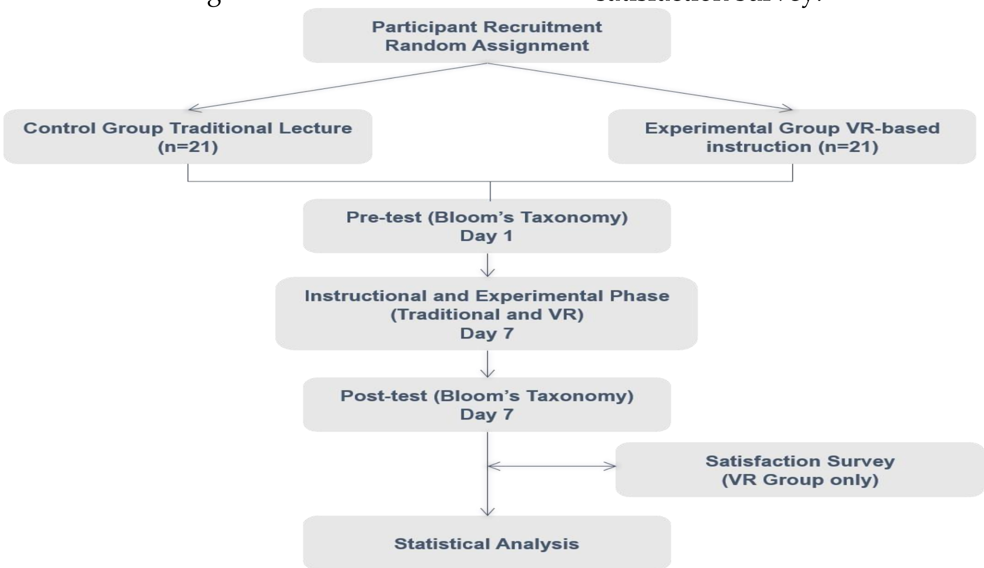

Figure 4: Experimental Timeline and Procedure.

Figure 5: Traditional and VR-Based Instructional Setups. (A: Traditional Instructional Setup. B: VR-Based Instructional Setup).

2.7. Data Analysis

Descriptive statistics were employed to encapsulate test results and survey responses. The Wilcoxon signed-rank test evaluated intra-group variations between pre-test and post-test for inferential analysis. Mann-Whitney U test The U test compared post-test scores of the two teaching groups. All analyses were performed utilising SPSS v26, with a significance threshold set at $\alpha = 0.05$.

A post hoc power analysis was performed via G*Power. With a sample size of 21 per group, an alpha level of 0.05, and an anticipated big effect size of 0.8, the analysis verified that the study possessed adequate statistical power of 0.80 to identify significant differences between groups through non-parametric tests.

3. RESULTS

3.1. Sample Characteristics

Forty-two undergraduate architecture students participated in the project, with 21 allocated to the experimental (VR) group and 21 to the control group. The average age of participants was 22.6 years (SD = 1.69) in the control group and 22.57 years (SD = 1.69) in the VR group. The control group comprised 12 females and 9 males, whereas the VR group consisted of 14 females and 7 males. All individuals possessed similar academic qualifications and lacked prior experience with the virtual reality content utilised in the study.

3.2. Knowledge Acquisition Outcomes

A 12-item assessment grounded in Bloom's Taxonomy was conducted prior to and during the instructional intervention to evaluate cognitive advancements. Scores were normalised to a 10-point scale to improve clarity. Descriptive and inferential statistical analyses were performed to assess variations in learning outcomes both within and among the educational groups.

Pre-Test Comparisons: At baseline, both groups exhibited equivalent levels of knowledge. The control group had a mean pre-test score of 6.49 (SD = 0.881), whereas the VR group attained a score of 6.25 (SD = 0.869). A Mann–Whitney U test indicated no statistically significant difference between groups before the intervention (U = 491.0, p = 0.327), implying baseline parity in subject matter comprehension.

Post-Test Performance: In accordance with the instructions, both groups demonstrated enhancements in test performance. The control group's mean post-test score rose to 6.92 (SD = 0.832), whereas the VR group attained a mean score of 8.20 (SD = 0.917). The intra-group enhancement was statistically significant for both cohorts according to Wilcoxon signed-rank tests:

- Control group: Z = −3.62, p < 0.001
- VR group: Z = −3.83, p < 0.001

The Mann–Whitney U test indicated a statistically significant difference in post-test scores between groups, favouring the VR group (U = 1265.0, p = 0.004). This discovery demonstrates that immersive VR-based training resulted in superior information acquisition compared to traditional lecture-based methods.

Variability and Distribution: Figure 6 demonstrates that the VR group displayed a significant enhancement in both median and mean scores, accompanied by a reduced interquartile range, indicating enhanced performance and increased consistency among learners.

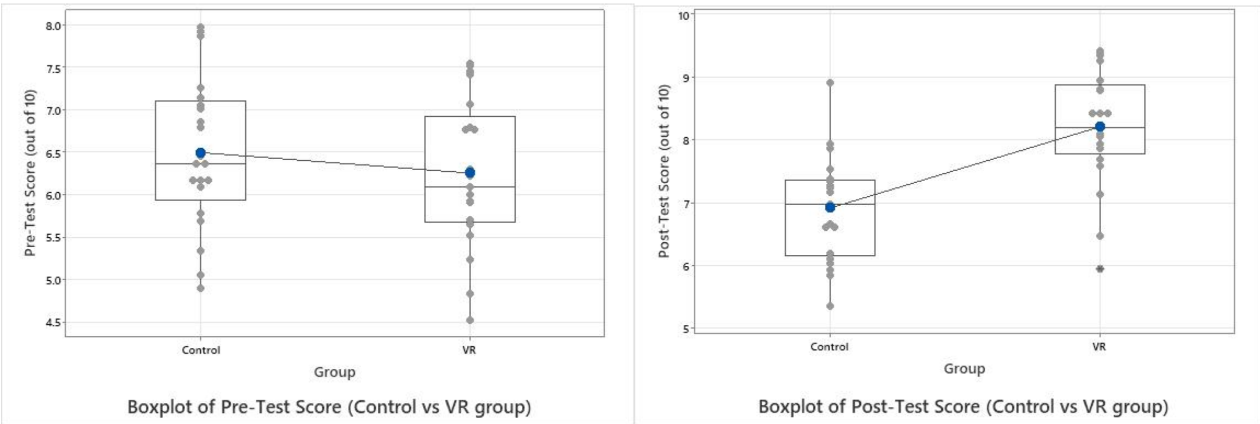

Figure 6: Boxplots Comparison of Pre and Post-Test Scores.

3.2.1. Domain-Level Knowledge Outcomes by Instructional Method

To elucidate the impact of instructional modality on distinct cognitive processes, average post-test scores were examined across the six domains of Bloom's taxonomy Remembering, Understanding, Applying, Analysing, Evaluating, and Creating. Table 1 and the corresponding line chart (Figure 7) depict the average scores for each domain in both the control group and the VR group. The VR group excelled over the control group in four of six domains. The most significant performance disparity was observed in the Applying domain, where the VR group attained a markedly superior mean (1.867, SD = 1.304) relative to the control group (1.194, SD = 0.927). This indicates that immersive VR environments may more effectively facilitate the conversion of conceptual understanding into practical application.

The VR group demonstrated elevated average scores in:

- Remembering (1.434 vs. 1.151)
- Understanding (1.673 vs. 1.565)
- Evaluating (1.357 vs. 0.904)

Highlighting the prospective advantages of virtual reality in facilitating both basic recall and advanced evaluative cognition. Nevertheless, the control group marginally surpassed the VR group in the Creating domain (0.947 vs. 0.775), while both groups exhibited similar scores in Analysing (1.159 vs. 1.106), suggesting that the brief VR exposure may inadequately promote the synthesis and production of novel ideas. These findings underscore the efficacy of VR in promoting knowledge transfer and applied reasoning, while its impact on ideation and synthesis may necessitate prolonged exposure.

Table 1: Mean Post-Test Scores Categorized by Bloom's Domain across Instructional Methods.

Bloom's taxonomy Domain	Control Group (n = 21)	VR Group (n = 21)
Remembering	1.151 (SD = 0.799)	1.434 (SD = 0.848)
Understanding	1.565 (SD = 1.091)	1.673 (SD = 0.868)
Applying	1.194 (SD = 0.927)	1.867 (SD = 1.304)
Analyzing	1.159 (SD = 0.799)	1.106 (SD = 1.176)
Evaluating	0.904 (SD = 0.453)	1.357 (SD = 0.908)
Creating	0.947 (SD = 0.678)	0.775 (SD = 0.703)

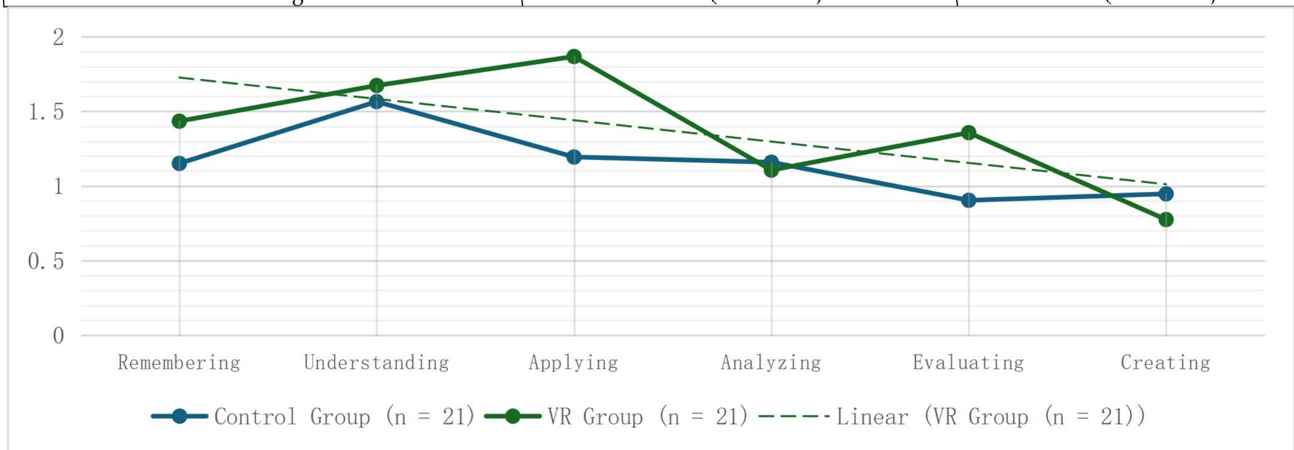

Figure 7: Line Chart Comparison of Mean Post-Test Scores across Bloom's Domains for Control and VR Groups.

3.3. Student Satisfaction with VR-Based Instruction

A satisfaction questionnaire was presented to students in the VR group (n = 21) to evaluate their perceptions of the immersive learning experience after the instructional session. The 11-item test employed a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) to assess perceived instructional advantages of VR across cognitive, emotional, and experiential learning domains. Table 2 delineates the detailed responses, showcasing the mean and standard deviation for each statement.

Table 2: Student Perceptions of Educational Effectiveness and Satisfaction with VR-Based Instruction (n = 21).

No.	Statement	Mean	SD
1	The VR experience helped me visualize architectural concepts more clearly.	4.52	0.51
2	The immersive nature of VR enhanced my understanding of local architectural elements.	4.20	0.57
3	Learning through VR promoted deeper engagement with the subject matter.	4.48	0.50
4	VR enabled me to actively explore spatial and cultural aspects of architecture rather than passively observe them.	3.90	0.60

5	Experiencing the architectural environment in 3D improved my retention of course content.	3.75	0.66
6	VR-based learning stimulated my creative thinking and design reflection.	3.60	0.61
7	The VR session increased my motivation to learn about architectural heritage.	4.38	0.58
8	Interacting with the VR environment helped me grasp complex spatial relationships more effectively.	3.95	0.63
9	The realism of the VR model contributed to a stronger emotional and cognitive connection with the content.	3.10	0.79
10	I would like to see VR integrated into other theoretical architecture courses to improve learning outcomes.	4.00	0.59
11	Overall, I was satisfied with my learning experience using VR in this course.	4.05	0.53

*Figure 8: Blue **High perceived value,** Black **Overall satisfaction,** Gray **Lower Perceived Value or limited impact.***

The findings indicated predominantly positive sentiments towards VR-based training, with discrepancies in perceived effectiveness across several facets of the learning experience. Three items attained elevated satisfaction ratings (mean ≥ 4.3), signifying robust student consensus that VR augmented their capacity to visualise architectural concepts (M = 4.52, SD = 0.51), fostered deeper engagement with the subject matter (M = 4.48, SD = 0.50), and enhanced their motivation to learn (M = 4.38, SD = 0.58). Six items received moderate satisfaction ratings, with mean scores ranging from 3.6 to 4.2. Students recognised that virtual reality enhanced their comprehension of local architectural features (M = 4.20, SD = 0.57), facilitated a more effective examination of spatial linkages (M = 3.95, SD = 0.63), and promoted active exploration rather than passive observation (M = 3.90, SD = 0.60). Moderate reactions were observed for information retention (M = 3.75, SD = 0.66), stimulation of creative thinking (M = 3.60, SD = 0.61), and the inclination to utilise VR in forthcoming architectural courses (M = 4.00, SD = 0.59). Significantly, one item received a low rating, as students demonstrated less consensus regarding the extent to which the realism of the VR simulation augmented their cognitive or emotional engagement with the architectural content (M = 3.10, SD = 0.79). This indicates possible constraints in the effectiveness of the simulated environment in conveying emotional or symbolic architectural signals.

The overall satisfaction item received a moderate-to-high assessment (M = 4.05, SD = 0.53), suggesting that students typically regarded the VR experience as a satisfying and effective instructional tool. These findings indicate that although VR was positively received in cognitive and motivational aspects, further enhancement of virtual realism and symbolic representation could improve its emotional and affective influence.

4. DISCUSSION

This study illustrates the capacity of immersive VR to markedly improve knowledge acquisition and learner satisfaction in a theoretical Local Architecture course. This section examines these findings within the framework of educational theory and existing research.

4.1. Knowledge Acquisition in VR vs. Traditional Instruction

The findings demonstrate that both instructional approaches yielded within-group learning advancements, although the enhancement was markedly more in the VR cohort. The post-test scores of the VR group (M = 8.20/10) exceeded those of the control group (M = 6.92/10), with a statistically significant difference ($p = 0.004$). This corroborates previous studies indicating that virtual reality enhances recall, comprehension, and engagement relative to conventional or multimedia training (Radianti et al., 2020).

The domain-specific study indicated particularly pronounced results in the "Applying" cognitive domain, where VR users markedly surpassed the control group. This corresponds with Mayer's cognitive theory of multimedia learning, which posits that VR's incorporation of dual channels (visual and interactive) improves learners' capacity to translate theoretical knowledge into practical application (Mayer, 2009). These results align with the experimental findings of Kowalski et al. (2020), who documented improved spatial reasoning and logical analysis resulting from VR learning in architectural contexts. Substantial improvements were observed in the "Remembering," "Understanding," and "Evaluating" domains, indicating that VR successfully facilitates both lower- and higher-order cognitive processes. Significantly, "Creating" shown no enhancement possibly attributable to the restricted exposure period and the intrinsically constructive essence of creative cognition, which may necessitate iterative design processes absent in a single-session intervention.

4.2. Student Satisfaction and Perceived Effectiveness

The satisfaction survey reveals a strong overall endorsement of VR for educational purposes, with average satisfaction levels varying from moderate to high across essential parameters. "Visualization," "engagement," and "motivation" got the highest scores ($M \geq 4.3$), indicating VR's ability to enhance affective and cognitive immersion in educational settings (Allcoat & von Mühlenen, 2018; Makransky & Petersen, 2021). Conversely, the measure evaluating "emotional/cognitive connection through realism" attained a significantly lower score (M = 3.10), signifying constraints in VR's capacity to emulate emotional profundity. This corroborates other research indicating that realism, although its significance, may not fully capture the sensory and emotional aspects of actual architecture (Naz et al., 2017). The incorporation of an overall satisfaction metric (M = 4.05) underscores the educational significance of VR, consistent with student-centered instructional theories (Keller, 1987; Piaget, 2003) that assert engagement, relevance, and satisfaction as essential components of effective learning.

4.3. Theoretical and Practical Implications

These findings validate constructivist theories of experiential learning by actively engaging with spatial settings in VR, learners internalise architectural concepts in ways that surpass passive observation (Piaget, 2003; Vygotsky, 1980). The capability of VR to replicate authentic spatial experiences enhances cognitive load theory by providing controllable, visually directed learning experiences (Chao et al., 2017). From a pragmatic perspective, the findings support the need for integrating VR into architectural education particularly for theoretical courses that conventionally depend on texts and two-dimensional visuals. Previous research similarly underscores VR's capacity to emulate field-based learning experiences, indicating its potential to replace certain aspects of fieldwork in resource-constrained environments (Bernstetter et al., 2025; Ferdani et al., 2020; Genge et al., 2024; Zhao et al., 2021).

4.4. Limitations and Future Directions

Notwithstanding the favourable results, the study possesses some limitations that merit attention. The intervention was implemented during a brief period, utilising a singular case study (the Raghadan Tourist Terminal) located inside a defined geographical context (Amman, Jordan). The restricted geographic and typological scope constrains the external validity and generalisability of the findings to wider architecture education contexts. The limited sample size ($n = 42$) may restrict the statistical power to identify smaller effect sizes, yet it possesses sufficient power to detect larger effects. The sampling was confined to a single university with comparable academic profiles, potentially constraining the range of learner viewpoints and experiences. Third, while the VR experience markedly enhanced cognitive outcomes, its influence on higher-order creative synthesis and emotional engagement with architectural content was comparatively subdued. This may be ascribed to constraints in the authenticity of the virtual world, the short duration of exposure, or the lack of collaborative creative activities. Future research must rectify these deficiencies by utilising longitudinal study designs to evaluate knowledge retention, broadening the diversity of architectural case studies, and incorporating multi-institutional samples. Furthermore, subsequent research may investigate the effects of recurrent VR interventions, the significance of collaborative VR-based learning, and the incorporation of biometric or neurophysiological metrics (e.g., EEG, eye-tracking) to elucidate more profound aspects of engagement and immersion. The advancement of more symbolically and emotionally expressive VR settings may augment the tool's ability to communicate the cultural and phenomenological aspects of architectural education.

5. CONCLUSION

This study examined the effectiveness of immersive Virtual Reality (VR) as an educational instrument in architectural education, particularly in conveying theoretical knowledge concerning local architecture. The findings demonstrate that VR-based training improves student learning outcomes, especially in areas related to knowledge retention, understanding, and application, as classified by Bloom's taxonomy. The VR group exhibited markedly superior post-instruction performance compared to the control group, suggesting that immersive learning environments can successfully enhance cognitive growth across various complexity levels. Additionally, students reported elevated pleasure with the VR-based instructional style, especially with engagement, motivation, and conceptual clarity. These findings underscore the significance of VR as a learner-centred pedagogical approach that promotes both cognitive and emotional engagement. VR enables a profound comprehension of architectural principles and cultural settings through spatial immersion and sensory-rich experiences, which are frequently challenging to communicate via traditional lecture-based approaches. The findings indicate that incorporating VR into architectural curricula, particularly in theoretical and culturally significant areas like vernacular architecture, can enhance educational practices by connecting abstract concepts with practical learning. Consequently, immersive technologies possess significant potential to transform the educational framework in architectural studies, fostering more inclusive, participatory, and efficient learning environments.

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