Assessing Student-User Experience in Building Design Studios Using Advanced Intelligent Tools: A Pilot Study at the University

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Received: July 16, 2024 Accepted: August 18, 2024 Online Published: September 13, 2024

doi:10.5430/wje.v14n3p113 URL: https://doi.org/10.5430/wje.v14n3p113

Abstract

Recent advancements in technology have revolutionized various fields, including architecture education. However, studies exploring immersive realities in architectural design studios remain limited. This research addresses this gap by conducting a pilot study at the Architectural Engineering Intermediate Design Studio, which thoroughly explores the use of Virtual Reality (VR) to help architectural students enhance their design skills, detect design flaws and clashes between different systems, and provide valuable insights for the advancement of architectural education and practice. The study will adopt a qualitative methodology that utilizes in-depth interviews conducted with the students while they explore their designs using VR hardware. The research findings revealed the effectiveness of VR in identifying the following: Enhancing the visualization of design challenges, providing a comprehensive building assessment, and holistically detecting design qualities and system integration problems. The pilot study recommends integrating the use of VR into the curriculum of the intermediate design studio level at the University. The research findings will contribute to the current knowledge base and guide future advancements in immersive design technologies.

Keywords: architecture design studio, education, intelligent tools, virtual reality, university

1. Introduction

In the realm of architectural education, design studios serve as crucial environments for nurturing creativity and innovation among students, preparing them for real-world challenges in various industries. In recent years, the integration of advanced intelligent technological tools has shown efficiency in transforming traditional design studio practices, by offering new opportunities for enhancing the user experience and educational outcomes. This paper presents a case study conducted at the University, focusing on the assessment of user experience in design studios through the utilization of advanced intelligent tools such as Virtual Reality (VR).

Traditionally, architectural education relies on conventional teaching methods such as lectures, hand-drawn sketches, and physical models to develop students' skills, imagination, and knowledge. However, the architecture profession has evolved across the centuries to embrace digital technologies such as digital software, which has already been integrated into the architectural curriculum. Architecture is continuously undergoing a transformative evolution and a growing need to integrate advanced intelligent technologies into the architectural curriculum and help prepare students for contemporary practices (Xiang, Yang, Chen, Tang, & Hu, , 2020; Abdirad & Dossick, 2016; Ummihusna, Zairul, Ab Jalil, & Sulaiman, 2024).

Immersive reality has significantly altered the nature of collaboration in architecture overall and even in architecture education by providing students with immersive and interacting environments that help them visualize and experience their designs. The importance of presence when visualizing a design solution is critical in the architectural, engineering, and construction industries for achieving the aesthetic appearance of a space which will simulate the functionality of the design and allow an effective experience of the place in terms of factors such as safety and ergonomics (Yu, Gu, Lee, & Khan, 2022). A systematic review of architectural design collaboration in immersive virtual environments Designs. Previous studies on immersive virtual realities in architectural education explored its use to identify end-user lighting preferences in building design (Heydarian et al.; Niu et al., 2016).

Further studies related to the use of immersive environments were comparative studies, which compared user spatial perception in immersive versus traditional VR systems. (Paes et al.; Okeil, 2010; Özen et al., 2021). Another research has also highlighted the applications of virtual reality in areas such as architecture, landscape architecture, and environmental planning (Stancato, Piga, & Pogliani, 2023, August; Portman, Natapov, & Fisher-Gewirtzman, 2015).

Existing literature about the use of virtual or any immersive reality for education purposes showed a notable absence of any comprehensive study exploring the application of VR in detecting clashes between different systems within architectural designs. Another gap identified is the limited amount of research related to Understanding the effectiveness of VR as a comprehensive design tool, particularly within the context of architectural practices locally in the UAE. Therefore, this research aims to bridge the gaps by conducting a thorough investigation into the practical implications of VR in architectural education and practice in the architectural engineering department at the University. This will contribute to the current knowledge base and guide future advancements in immersive design technologies.

The significance of this research lies in its intention to systematically assess the effectiveness of Virtual Reality (VR) as an advanced intelligent tool in architectural practices, with a particular focus on enhancing user experience and improving design quality. This investigation will explore how VR can be facilitated to help architectural students enhance their design skills, detect design flaws and clashes between different systems for seamless integration, and provide valuable insights for the advancement of architectural education and practice. How can VR be facilitated to help students enhance the design quality from an architectural point of view? How does VR assist in identifying design constraints and conflicts between various systems to support the seamless integration and the incorporation of sustainable elements? The research adopted a qualitative research methodology using in-depth interviews with architectural students to answer the research questions.

The research results highlighted the effectiveness of VR technology in grasping and assessing various architectural design aspects specifically within the interior spaces and structural design issues (including clash detection within the integration of architectural structural systems), it also showed valuable results evaluating exterior building design. Findings from this investigation help contribute to the ongoing discourse on leveraging technology to optimize design education practices and foster innovation among students.

2. Literature Review

The architectural design process typically runs through a cycle of analysis, evaluation, and synthesis in the different design phases to reach its final output. Traditional methods for teaching architecture to improve students' knowledge and imagination, especially in the early years of architecture studies, mostly rely on lectures, hand-drawn sketches, and physical models. Over the centuries, the architecture profession evolved and embraced digital technologies and software programs. CAAD for instance has been introduced into architectural education curriculums worldwide with varied degrees of success (Achten, 1996) identified four types of computer systems in education: social, professional, educational, and innovative systems. All students entering higher education should be familiar with social systems, which are computer technologies that may be used throughout the curriculum. Professional systems in architecture include computer programs like AutoCAD, ArchiCAD, and Revit (Dare-Abel & Uwakonye, 2014). Assessment of Digital Architectural Design Education at Covenant University (Johansson, 2016).

Extended Reality (XR) encompasses various immersive technologies that alter the user's perception of reality. Virtual Reality (VR) immerses users in a completely synthetic, digitally produced environment, which fully immerses and disconnects from the physical world. Augmented Reality (AR), on the other hand, overlays digital content onto the real world, enhancing the user's perception of reality by adding virtual elements to their surroundings. Mixed Reality (MR) a term used interchangeably with AR, refers to blending virtual with real-world environments to create a seamless user experience (Vasarainen et al., 2021). The use of immersive technologies has recently made its way into the realm of education.

The significance of using Virtual reality for education is emphasized through several studies by its potential for enhancing student learning outcomes and motivations (Cibulka & Giannoumis, 2017), in their research that involved integrating VR in engineering education, believed that it enhanced student motivation and learning outcomes and fostered the development of crucial competencies for the 21st century workforce. The authors added that VR technology offers an immersive learning experience that enhances students' self-motivation and performance, improves their engineering skills, and reduces the demand for costly physical infrastructure. A study conducted by Al-Gindy, Felix, Ahmed, Matoug, & Alkhidir (2020), shows the VR's ability to improve students' engagement through its unparalleled integration and first-person perspective, knowledge retention, and learning experience. Most individual studies have concentrated on technical development, user experience, and scenario pilots of VR applications rather than social and practical uses (Vasarainen et al., 2021).

Virtual reality was integrated into various areas and levels of education at the school level or university. However, this paper will focus more on its use in higher education levels. Ibáñez et al. (2014) presented a mixed method comparative case study on the use of Gamification for Engaging Computer Science Students in Learning Activities. Results showed that the use of gamification improved students' motivation and increased their engagement. However, issues like the students' dependence on technology and well as lack of personalization for each student. Another study conducted by Niu et al. (2016) investigated the integration of virtual reality (VR) technology into the process of building energy design. The findings indicated that the use of virtual reality (VR) technology and the Design with Intent (DwI) method can be successfully integrated to capture user behavior data more effectively and optimize building energy design which will assist in building energy performance research (Dede, Jacobson, & Richards, 2017). The use of virtual reality in architectural education recently highlighted its significance in assisting students in understanding the integration of building construction and HVAC design and installation (Ahmed, Megahed, Al-Zaabi, Al-Sheebani, & Al-Nuaimi, 2022; Bande, Ahmed, Zaneldin, Ahmed, & Ghazal, 2022).

The use of immersive reality in architectural education has been used and investigated in several studies, Heydarian et al. discuss the use of immersive virtual environments to identify end-user lighting preferences in building design. Meanwhile, Paes et al.'s paper on the same page compares user spatial perception in immersive versus traditional VR systems. Mujber, Szecsi, & Hashmi, (2004), describe virtual reality applications in manufacturing process simulation. In another paper, Portman et al. discuss virtual reality's applications in architecture, landscape architecture, and environmental planning. Ceylan (2020, May), conducted a comparative study to investigate the use of Virtual Reality to Improve the Visual Recognition Skills of First Year Architecture Students and showed benefits in aspects such as students' perception of a model's physical characteristics, it also helped improve students' enthusiasm and contribution in the design studio courses.

A limited number of studies investigated the use of immersive technologies in design education within the UAE. One was conducted at the University by Okeil (2010) which examined a design case study that shows how user preferences can be used to improve the design of an office space. The study employed a quantitative research design that included environmental simulations based on the participants' lighting preferences. These simulations were then used to define the boundaries of useful daylight illuminance (UDI) and evaluate the generated designs. The study sought to demonstrate how having access to end-user lighting preferences can help improve building design. Okeil (2010). Other studies conducted at University focused on the use of VR in design studios Ahmed (2020, February) and building construction Ahmed (2020, February), Ahmed (2020, December). Another recent study was conducted by Aalkhalidi et al. (2022) from Sharjah University the research included 53 Interior Design students to measure students' general knowledge of VR, AR, and MR, and understand the challenges faced by institutions in implementing these technologies.

An overview of the research on the use of immersive virtual reality education, head-mounted display education, and Oculus Rift education. According to the review, most papers on immersive virtual reality education are in the computer science area, with a significant number related to medical issues. The number of papers published has been decreasing over the years, with 54 in 2013, 37 in 2014, and 2 in 2015. For head-mounted display education, the most common subject is computer science, and a significant number of papers referring to medical subjects have been found. The number of papers published in the United States is higher than in other nations. A literature review on immersive virtual reality in education: State of the art and perspectives. eLearning & Software for Education (Freina & Ott, 2015).

Existing literature about the use of virtual or any immersive reality for education purposes showed a notable absence of any comprehensive study exploring the application of VR in detecting clashes between different systems within architectural designs. Another gap identified is the limited amount of research related to Understanding the effectiveness of VR as a comprehensive design tool, particularly within the context of architectural practices locally in the UAE and at University the largest governmental university in the country. Therefore, this research intends to bridge these gaps by conducting an in-depth investigation into the use of VR technologies for architecture students and exploring its effectiveness in detecting design clashes and the integration of different building systems such as the structural, and passive systems. The study aims to shed light on the effectiveness of integrating advanced intelligent tools in design studio settings and their impact on enhancing the learning experience for students.

3. Method

The primary objective of this study is to assess the impact of integrating advanced intelligent tools, specifically Virtual Reality (VR) technology, into the design studio environment at the University. This research focuses on enhancing user experience and augmenting learning outcomes among students, exploring how VR facilitates immersive experiences, empowers informed design decisions, and fosters experiential learning in architectural engineering education.

A pilot study was conducted with a sample of five students from the Intermediate Building Design Studio class. Although deliberately limited, the sample represents approximately 50% of the selected class involved in the pilot investigation. The sample size is expected to be expanded in future research. Participants were randomly selected from the course names' list and chosen based on their availability for interviews. The final group comprised three females and two males. This class was specifically chosen due to its focus on developing detailed construction drawings and integrated design proposals, making it well-suited for evaluating the impact of VR technology on students with intermediate design knowledge.

The limited sample size was influenced by the depth and length of the interview sessions, which involved the use of VR devices. This process required significant preparation before, during, and after the interviews. Despite the small sample size, the in-depth nature of the study was designed to yield qualitative insights. Future studies will aim to expand the sample size to achieve broader generalizability. Selection criteria included current enrollment in the Intermediate Building Design Studio, a prerequisite understanding of architectural concepts, and the students' willingness to participate after receiving a thorough explanation of the research objectives.

Data collection involved structured interviews lasting approximately one hour each, designed to explore both general challenges and specific design aspects. Participants discussed the difficulties they encountered with advanced participatory tools in design, as well as analyzing various exterior and interior elements, including masses, cladding systems, materials, scale and proportions, lighting, furniture, interior landscaping, and circulation. The Intermediate Building Design Studio class was selected for this study due to its focus on developing detailed construction drawings and integrated design proposals, providing a suitable context for assessing the impact of VR technology on students with intermediate design knowledge.

During the interview sessions, four primary tools were utilized: Autodesk Revit for Building Information Modeling (BIM), Enscape 3D as a Revit plug-in for creating immersive VR experiences, an MSI Gaming Laptop to run the software applications, and the Meta Quest Pro as the VR hardware for immersive engagement. Ethical considerations were paramount throughout the research. Informed consent was obtained from all participants, ensuring confidentiality and anonymity. The research adhered to the principles established by the University's Institutional Review Board.

The interview questions were structured to move from the exterior of the building to the interior, covering the main key areas of building design. The in-depth interview included four questions:

1. Exterior Façade: Has VR helped you identify any problems with the façade and building form (e.g., façade grids, material, building form)?
2. Exterior Form: Did the VR experience help you identify issues with the shape and size of the building? If so, please specify and elaborate.
3. Interior Functionality: Has VR helped you address spatial problems in the interior space's shape and size (e.g., width of corridors, accessibility and wayfinding, floor areas, lighting, circulation, furniture)?
4. Interior Volumetric Sense: Has VR helped you identify problems with ceiling height, spatial experience, greenery, human scale, colors, and sense of place (or issues related to space perception and feelings when inside the space)?

Interview data will undergo qualitative thematic analysis. This analysis will identify patterns, insights, and recurring concepts derived from the interview transcripts, triangulated with observational data and participant feedback. This approach aims to provide a comprehensive understanding of the impact of VR integration on user experience and learning outcomes.

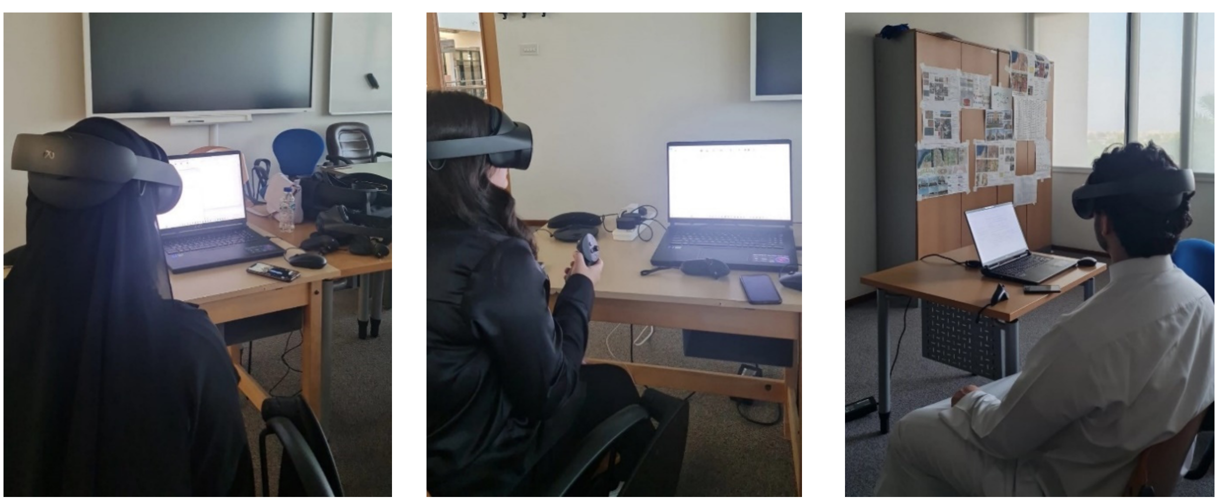
4. Results

The results section presents the findings derived from the students' evaluations of the advanced intelligent tool experience, specifically utilizing Meta Quest Pro for virtual reality (VR), focusing on both building exterior and interior aspects. Responses to specific questions (Q1-Q4) were analyzed to discern any issues or areas for improvement highlighted by the students. Each student's observations encompassed a range of factors, including the evaluation of the façade and building form, assessment of the shape and size of the building, identification of spatial challenges within the interior layout, and considerations regarding ceiling height, greenery, and overall atmosphere. Table 1 was carefully constructed to sum up the perspectives of each student regarding both the exterior and interior realms of the building, offering valuable insights into their individualized concerns and suggesting potential avenues for refinement gleaned from the immersive VR experiences.

Table 1. Summary of Students' Experiences with Virtual Reality (VR) Building Evaluation (Source: Author).

	Exterior Façade	Exterior Form	Interior Functionality	Interior Volumetric Sense
Student A	Louver spacing, Door proportions, Material color	Door proportions, Realism of building	Lighting, Stair positioning	Landscaping, Interior colors
Student B	Structure visibility, Material adjustments	Dome height, Wall height	Corridor proportions, Vertical circulation	Interior materials, Height
Student C	Material accuracy, Column integration, Building size	Building size, Landscaping	Vertical circulation, Structural system	N/A
Student D	Material accuracy, Level discrepancy	N/A	Handrail connection, Escalator design, Natural light,	Height discrepancies
Student E	Material realism, Cladding dimensions, Ground levels	Building size, Ground levels	Lighting needs	Lobby space, Ceiling height

Each student's engagement during the interview sessions offered unique individual insights into their experiences, perceptions, and challenges encountered while navigating the virtual realms. Figure 1 shows the essence of these collaborative discussions, showing the collaborative effort in this study.



(a) (b) (c)

Figure 1. Virtual Reality (VR) In-Depth Interview Session with Selected Students (Source: Author).

Student A identified discrepancies in louvers spacing and door proportions between their Revit model and the VR experience, indicating a need for adjustments in the design phase to achieve desired outcomes (Figure 2). He also highlighted the importance of realistic representation in VR for understanding building proportions and spatial relationships. In terms of interior spatial problems, the student noted issues with lighting and stair positioning, suggesting areas for improvement in functional aspects of his design. Also, he wanted to enhance the interior ambiance through landscaping and color choices.

(a) (b)

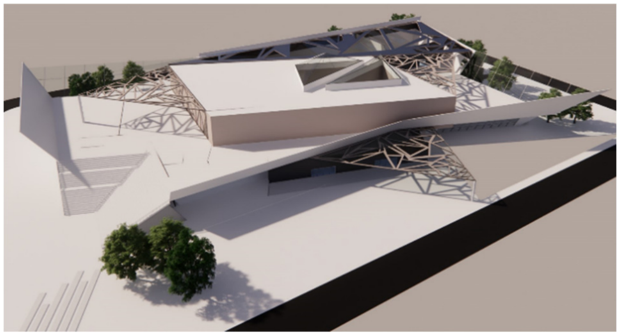
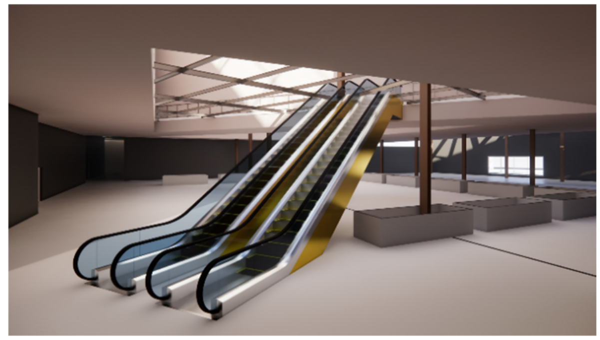
Figure 2. Student A Design Model, Exterior and Interior Shots Using Enscape Software (Source: Author).

Student B recognized structural visibility and material adjustments as key areas needing attention in the building façade (figure 3). She also noticed the need for modifications to the dome and wall heights based on her VR experience, indicating a discrepancy between her initial design expectations and the VR visualization. Interior spatial concerns focused on corridor proportions and vertical circulation, highlighting the importance of optimizing flow and accessibility within the building. The student also identified interior material and height discrepancies as factors impacting the space's overall atmosphere.

(a) (b)

Figure 3. Student B Designs Model, Exterior and Interior Shots Using Enscape Software (Source: Author).

Student C emphasized the need for accuracy in material representation and integration of exterior columns (figure 4). She also commented on the perceived scale of her building design and the importance of landscaping in enhancing the overall visual appeal. Regarding interior spatial problems, the student noted challenges with vertical circulation and structural system integration, indicating potential limitations in design implementation. However, she did not identify specific concerns related to ceiling height or interior atmosphere.

(a) (b)

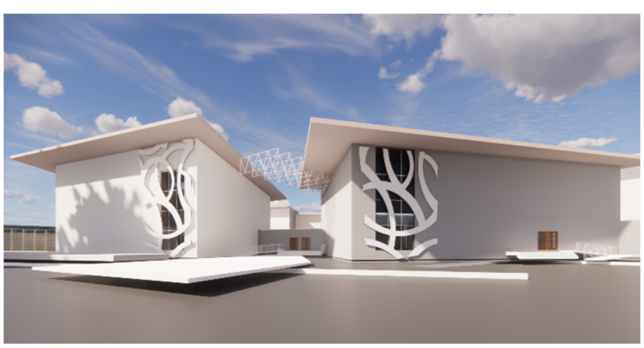
Figure 4. Student C Design Model, Exterior and Interior Shots Using Enscape Software (Source: Author).

Student D identified material accuracy and level discrepancies as significant issues affecting the building facade's realism (figure 5). However, he did not express concerns regarding the size or shape of the building. Interior spatial observations focused on handrail connections, escalator design, and natural light, indicating a keen eye for functional details and user experience considerations. The student also noted height discrepancies within the interior space as a factor influencing overall comfort and usability.

(a) (b)

Figure 5. Student D Design Model, Exterior and Interior Shots Using Enscape Software (Source: Author).

(a) (b)

Figure 6. Student E Design Model, Exterior and Interior Shots Using Enscape Software (Source: Author).

Student E highlighted the importance of realistic material representation in VR, particularly in understanding cladding dimensions and ground levels (figure 6). She also noted discrepancies in building size and exterior ground levels, indicating a need for adjustments to achieve desired spatial relationships. Interior spatial concerns centered on lighting needs and ceiling height, suggesting opportunities for enhancing comfort and ambiance within the building. Additionally, the student identified a specific issue with the lobby space, indicating a potential need for redesign or optimization.

5. Discussion

The findings of this study underscore the transformative potential of Virtual Reality (VR) technology in enhancing architectural design education, particularly in the context of the University (UNIVERSITY). Through in-depth interviews, students provided valuable insights into the various ways in which VR technology enhances the design process and improves learning outcomes. VR technology offers a realistic visualization of design challenges related to the dimensions and integration of cladding systems with exterior walls. By immersing students in virtual environments, VR facilitates a more precise understanding of spatial relationships and potential obstructions caused by columns within interior spaces. Moreover, the technology clarifies the identification of cladding materials and colors, enabling students to make informed design decisions (Ceylan, 2020, May).

The immersive VR experience aids in uncovering unexpected design issues, such as the need for shading and interior space redesign to optimize functionality (Liang & Sharudin, 2023). Students noted an improved perspective on the scale and design cohesion of entire buildings, including roof structures and building openings, compared to traditional 3D modeling software like Revit. Additionally, VR technology enables the identification of surface evenness issues, ground-level variations, and proportional balance problems in spaces like lobbies, corridors, and ceiling height. VR technology allows for a comprehensive evaluation of the spatial layout and functionality of interior spaces, addressing challenges associated with floor circulation, structural integration, and the need for interior landscaping. Students also identified discrepancies in the integration of vertical circulation elements, such as staircases and lifts, with structural systems and floors (Niu, Pan, & Zhao, 2016).

This study's findings contribute to the existing literature on VR technology used in architectural education and practice. Previous studies have highlighted the general usefulness of VR in expanding users' spatial understanding and providing realistic visualization. However, this study adds valuable information by specifying the major areas in which VR assists architectural students, including cognitive thinking in basic design education, visual design perception, and support for basic design solution development. Significant structural clashes were detected by students in the VR environment, highlighting the role of VR in expanding spatial understanding and facilitating the identification of clashes in integrating building systems. This finding aligns with previous literature recommendations for the use of VR to enhance cognitive thinking and support design solution development in architectural education.

In addition to the insights gathered from the in-depth interviews, a significant portion of students highlighted specific challenges related to vertical circulation and structural integration within their designs. Many students noted misunderstandings and errors in the vertical circulation elements, particularly concerning escalators, elevators, and staircases. These issues underscore the importance of accurately integrating these elements into the architectural design to ensure functional and efficient circulation throughout the building. Moreover, students identified challenges in the integration of structural elements such as columns, beams, and trusses, especially in complex architectural features like domes and skylights. Structural clashes and inconsistencies were commonly observed, emphasizing the need for precise coordination and integration of these elements to maintain design integrity and structural stability. By addressing these additional findings, this study provides further insights into the practical implications of VR technology in architectural education. Understanding the specific challenges faced by students in vertical circulation and structural integration can inform curriculum development and instructional strategies to better prepare students for real-world architectural practice (de Vasconcelos, 2021; Aydin & Aktaş, 2020; Angulo, 2015).

The research findings aligned with previous research as it emphasized the effectiveness of the use of VR technology architecture technology (Stancato, Piga, & Pogliani, 2023, August; Heydarian, Pantazis, Wang, Gerber, & Becerik-Gerber, 2017; Paes, Arantes, & Irizarry, 2017). The technology helped in grasping and assessing various aspects specifically interior spaces (lighting levels, scale, and proportion) and structural design issues including clash detection within the integration of architectural structural systems (Özen et al., 2021; Heydarian, Pantazis, Wang, Gerber, & Becerik-Gerber, 2017), it was also found to be effective in identifying problems related to the building's exterior design. This research's comprehensive investigation is unique because it contributes to architectural design studio education by bridging the discourse on leveraging technology to optimize design education practices and foster innovation among students.

While this study provides valuable insights into the effectiveness of VR technology in architectural education, several limitations should be acknowledged (Maghool, Moeini, & Arefazar, 2018). Firstly, the sample size and selection process may limit the generalizability of the findings, as the study involved a small cohort of students from a specific course. This restricted pool of participants may not fully represent architectural students' diverse perspectives and experiences overall. Additionally, evaluating user experience in VR is inherently subjective, as individual perceptions and preferences can vary widely. This subjectivity introduces a level of uncertainty to the study results, as participants' interpretations of the VR experience may differ. Furthermore, participants may exhibit response bias, providing answers influenced by factors such as social desirability or familiarity with VR technology. These biases can affect the accuracy and reliability of the data collected, potentially skewing the study outcomes. Despite these limitations, this research serves as a valuable starting point for further exploration into the integration of VR technology in architectural education. Future studies should aim to address these limitations by employing larger and more diverse samples, implementing rigorous methodologies to minimize subjectivity, and accounting for potential biases in participant responses.

5. Conclusion

This study aims to assess the efficiency of using advanced intelligent technologies such as immersive virtual reality in architectural education design studios, focusing on intermediate design studio courses. This research explored how VR can be assisted to help architectural students enhance their design skills, detect any design flaws and clashes between the different building systems to achieve full integration, and provide valuable insights for the advancement of architectural education and practice. The research also explored How VR can help students enhance the design quality from an architectural point of view. It assists in identifying design constraints and conflicts between various systems to support the seamless integration and the incorporation of sustainable elements. These research questions were answered using a full in-depth interview as a pilot study conducted with five students. The interview included four main questions which covered all the architectural issues from the general challenges to the building's exterior elements and the interior architecture passive elements, circulation, and the building systems integration and circulation. The integration of VR technology into architectural design education offers promising opportunities for enhancing the design process, improving learning outcomes, and preparing students for contemporary architectural practice. Moving forward, further research is needed to explore the long-term effects of VR integration and its potential to revolutionize architectural education and practice. Moving forward, future research could involve phase 2 of this study, which suggests fostering collaboration between students and instructors using VR technology to facilitate more effective discussions about design issues. By leveraging VR for collaborative design reviews, students can receive real-time feedback and guidance from instructors, fostering a more interactive and immersive learning experience. This collaborative approach can further enhance the effectiveness of VR integration in architectural education and practice.

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Acknowledgments

Not applicable.

Authors contributions

Not applicable.

Funding

Not applicable.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Sciedu Press.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.