AUGMENTED REALITY TECHNOLOGIES IN ARCHITECTURAL DESIGN EDUCATION: A SYSTEMATIC LITERATURE REVIEW

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Abstract: This systematic literature review investigates the integration and impact of Augmented Reality (AR) technologies in architectural design education. The study covers the period from 2019 to 2024 and explores the potential benefits of enhancing conventional design studio education with AR technologies. The review adhered to PRISMA guidelines and examined articles from ScienceDirect, the Web of Science (WoS), and Scopus databases. Results indicate that AR technologies positively influence various components of design studio education, fostering experiential learning. However, most studies focus on specific aspects of design studio education, suggesting further exploration. This review guides students, educators, and researchers in navigating the intersection of AR technologies and architectural design education. Notably, it underscores the necessity for a comprehensive evaluation and highlights the advantages and challenges of this innovative approach.

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Introduction

The utilization of Augmented Reality (AR) technologies is progressively rising in architectural design education, presenting novel methods to enrich learning experiences and pedagogical approaches. Digital content onto physical surroundings, AR facilitates immersive and interactive learning settings that actively involve students in hands-on learning exercises. Incorporating AR technologies into architectural design education has recently garnered increasing interest from educators, researchers, and professionals alike.

This systematic review of literature from 2019 to 2024 examines the assimilation and repercussions of AR technologies within architectural design education. The review delves into the potential advantages of integrating AR technologies into traditional design studio education, specifically focusing on comprehending these technologies' impact on learning achievements, spatial aptitudes, and student engagement.

The adoption of AR technologies in architectural design education demonstrates the potential to revolutionize conventional pedagogical methodologies and enhance students' educational experiences. Through the provision of virtual overlays depicting architectural models, urban settings, and design simulations, AR technologies empower students to visualize and engage with intricate spatial concepts in real-time, thereby nurturing profound comprehension and ingenuity in the design process.

This research endeavor aims to holistically amalgamate existing AR technologies in architectural design education studies by systematically reviewing literature from esteemed databases such as ScienceDirect, Scopus, and the Web of Science. The review seeks to pinpoint principal themes, patterns, and obstacles in integrating AR technologies into design studio education by scrutinizing and amalgamating findings from diverse research endeavors.

Ultimately, this scrutiny furnishes students, educators, and researchers with invaluable insights for navigating the intersection of AR technologies and architectural design education. The study strives to guide forthcoming research initiatives and contribute to the persistent scholarly dialogue on innovative pedagogical practices in architectural education by accentuating both the prospective benefits and hurdles associated with integrating AR technologies.

The State of the Art

Augmented Reality (AR) technologies are increasingly integrated into architectural design education, offering innovative avenues to enrich learning experiences. Studies by Darwish et al. (2023) and Hartless et al. (2020) demonstrate that (AR) improves students' spatial cognitive skills and tacit knowledge acquisition. Through immersive AR experiences, students engage with architectural concepts, fostering enhanced understanding and proficiency. Spitzer et al. (2022) propose decision-making frameworks for integrating AR technologies into curriculum design. Despite potential advantages, challenges such as technological proficiency disparities (Cakici et al., 2021) warrant attention. Future research should

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address these gaps to maximize AR's benefits in architectural education, emphasizing comprehensive evaluation (Hussein, 2023).

Methodology

The study adopts a systematic review methodology characterized by meticulous and transparent information analysis from various studies addressing a specific research question. It involves systematic searching, careful selection, and critical evaluation of relevant literature, followed by a comprehensive synthesis of findings. The primary research questions focus on how Augmented Reality (AR) experiences are employed in architectural design studio education, their effects on learning experiences, and their intensity in the studies of the architecture field. A literature search spanning 2019 to 2024 was conducted using ScienceDirect, Scopus, and the Web of Science databases, with keywords relevant to the research questions. Selected studies specifically explored experiential learning in architectural design studios, particularly utilizing AR technologies. The study adheres to PRISMA guidelines for transparent and comprehensive reporting. It aims to provide an evidence-based understanding of the impact of digital technology, particularly AR, on experiential learning in architectural design education and practice.

Eligibility Criteria

The eligibility requirements for this research acknowledge the refined progression of architectural design studio education with the incorporation of AR technology; the study's objective is to investigate the future path of design education. By amalgamating literature from esteemed databases such as ScienceDirect, Scopus, and the Web of Science, the research maintains rigorous selection criteria to offer significant stakeholder perspectives and contribute to the ongoing scholarly discussion in the field (Table 1).

Table 1: Systematic Literature Review Results in Science Direct, Scopus, WoS Databases.

Database	Query Formula/Terms	Document Type	Research Area	Results
Science Direct	Find articles with these terms: Augmented Reality Technologies in Architectural Design Education	Review article, research article	Engineering, Social Sciences,	1098
Scopus	TITLE-ABS-KEY (augmented AND reality AND technologies AND in AND architectural AND design AND education) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))	Review article	-	20
Web of Science	Augmented Reality Technologies in Architectural Design Education (All Fields) and Article or Review Article (Document Types) and English (Languages) and Review Article or Article (Document Types) and 2020 or 2021 or 2022 or 2023 or 2024 (Publication Years) and Review Article or Article (Document Types)	Review article	-	37
TOTAL				1155

Source: Science Direct, Scopus, WoS Databases

Inclusion Criteria

The eligibility criteria outline the parameters for selecting studies that examine the integration of augmented reality (AR) technology in architectural design studio education. These criteria emphasize investigations exploring the application and effects of AR within this educational context, focusing on articles published in English between 2019 and 2024. The selection process prioritizes papers addressing AR and architectural design studio education, especially those investigating the use of AR technologies for experiential learning in architectural design studios.

Exclusion Criteria

The exclusion criteria for this systematic literature review involve filtering out studies not focused on AR technologies, those unrelated to higher education or architecture, and any off-topic or divergent works. Only papers directly aligned with the review's focus on AR technologies in architectural design studio education were included. Non-English studies and duplicate publications were also excluded to ensure methodological rigor and the selection of relevant sources. Following a well-defined procedure, the review process involved identifying, screening, and including articles, resulting in the exclusion of numerous papers based on specific criteria: duplicates (n=7), scholarly works unrelated to augmented reality (n=125), content not related to higher education (n=9), material not focused on architecture (n=968), studies conducted outside architectural design education (n=35), and those not aligning with the review's objectives (n=0), as well as one unreachable source. This systematic process identified ten papers as most relevant to the study's aim. These papers were evaluated based on their aims and conclusions to explore the utilization of AR technology in architectural design studio education (Table 2).

Table 2: Most Related Papers as a result of Systematic Literature Review

No	Topic	Author(s)	Aim	**Method**	Conclusion
1	Extended reality for enhancing spatial ability in architecture design education.	Darwish et al. 2023	Explore the influence of Extended Reality technology on the spatial cognitive skills of students. Analyze the association between the utilization of XR technology and the participants' academic performance.	A general spatial ability test was administered at baseline and after the project's completion. The utilization of XR technology was integrated into the initial design studio for an experimental investigation.	The utilization of XR technology led to a notable enhancement in the students' spatial ability scores. The main objection to the study focused on the missing control group.
2	Trends and Research Issues of Augmented Reality Studies in Architectural and Civil Engineering Education	Diao et al. 2019	Examine trends in augmented reality (AR) and research challenges within the realm of education in architectural and civil engineering.	Examination grounded on AR development tools, classifications of systems, and educational apparatus. Application of visual inertial odometry (VIO) in the context of instantaneous localization monitoring.	Augmented Reality (AR) is applied in various educational methodologies and learning specific to particular domains. Cooperation plays a crucial role in the amalgamation of research in AR within the realm of education.
3	Augmented reality experience in an architectural design studio	Cakici et al. 2023	Examine the inclination of students towards novel forms of representation in the field of architectural design. Examine the relationship between Augmented Reality technologies and the design proficiency of students.	Emerging technologies such as augmented reality, along with software tools like Rhinoceros and Grasshopper, are being utilized in various fields. The utilization of survey methodology is crucial in investigating the possibilities of augmented reality in the realm of architectural education.	A strong correlation was observed between gender and the utilization of computer programs in designs. A robust correlation was observed between gender and the utilization of computer programs in designs.
4	Extended reality in AEC	Trindade et al. 2023	To provide an overview of extended reality application in the architecture, engineering, and construction (AEC) industry.	A systematic review conducted. The formulation and implementation of precise taxonomies were employed to categorize the research findings.	The conclusions center on XR applications within the fields of architecture, engineering, and construction.

5	A Worldwide Journey through Distance Education— From the Post Office to Virtual, Augmented and Mixed Realities, and Education during the COVID-19 Pandemic.	Pregowska et al. 2021	To offer a comprehensive examination of the evolution of distance education.	An exploration of the historical advancement of distance education in secondary and higher education.	- Examination of the historical development of distance education in both secondary and higher educational settings. Investigate the profound effects of the swift changes in the educational process resulting from the COVID-19 pandemic.
6	Framework for the Use of Extended Reality Modalities in AEC Education	Spitzer et al. 2022	A decision-making framework is put forth for the selection of XR technologies in the field of education. To authenticate the framework, a summer camp was conducted at the School of Building Construction.	- Systematic literature review of 983 papers from Scopus digital library. The development and utilization of particular taxonomies for the purpose of consolidating research.	XR interventions have been validated to elevate levels of engagement, self-efficacy, and student learning. A framework for decision-making aids educators in the AEC industry in the selection of suitable XR technologies.
7	Integrating augmented reality technologies into architectural education: application to the course of landscape design at Port Said University	Hussein 2023	- In order to investigate the advantages of incorporating Augmented Reality (AR) technology in the realm of landscape design education. - With the aim of enhancing students' understanding of the intricacies involved in the landscape design procedure.	A systematic review of 983 academic publications retrieved from the Scopus digital repository was conducted. The development and utilization of precise categorization systems to summarize the body of research were implemented.	- The integration of Augmented Reality (AR) has a positive influence on the field of landscape design education. - The utilization of AR technology contributes to an enriched learning experience for students, leading to a deeper understanding and acquisition of knowledge.
8	The Application of Extended Reality Technology in Architectural Design Education: A Review	Jingwen et al. 2023	- Investigate the utilization of XR technology in construction education within the preceding 5 years. - Assess the advantages and disadvantages of XR technology in the realm of architectural education. Recognize potential avenues for further research on extended reality technology in the educational sector.	- Conducting content analysis for the purpose of synthesizing and evaluating research outcomes. - The process of categorizing and scrutinizing documents according to specific classification standards.	XR technology enriches the field of architectural education by elevating the efficacy of instructors and fostering increased levels of student engagement. It is probable that XR technology will supplant conventional pedagogical approaches within educational settings.

9	Comparison of Building Design Assessment Behaviors of Novices in Augmented- and Virtual-Reality Environments	Hartless et al. 2020	Investigate the adoption of Augmented Reality (AR) and Virtual Reality (VR) in advancing tacit knowledge.	Engaging Augmented Reality (AR) and Virtual Reality (VR) in empirical observations to boost tacit knowledge acquisition. - Employing pre- and post-questionnaires, statistical assessments, and video documentation as methodologies for data gathering.	The utilization of AR and VR technologies facilitates activities that simulate tasks suitable for individuals confined to wheelchairs. Using AR and VR technologies promotes activities that replicate tasks suitable for individuals confined to wheelchairs. AR, in particular, catalyzes fostering physical exploration and interaction within a group of participants. Implementing AR and VR technologies provides students with immersive educational experiences resembling real-life situations.
10	Impact of extended reality on architectural education and the design process	Kharvari et al. 2022	XR technologies optimize the various stages of the design process and enhance educational achievements. Applicable for the field of professional architectural design, it also facilitates the participation of end-users throughout the process.	- The Modified PICO strategy and framework analysis were employed for the systematic review. - Studies of a conceptual nature and proposals based on theory but lacking information on ARVR technology were omitted.	XR technologies optimize the various stages of the design process and enhance educational achievements. Applicable for the realm of professional architectural design, these technologies facilitate the inclusion of end-users throughout the design process.

Source: Science Direct, Scopus, WoS Databases

Analysis of Results

The systematic review on Augmented Reality (AR) in architectural design education reveals consistent findings across various studies. Darwish et al. (2023) and Kharvari et al. (2022) both demonstrate that Extended Reality (XR) technologies enhance spatial abilities and overall educational outcomes. Diao et al. (2019) and Hartless et al. (2020) emphasize the broad applicability of AR and Virtual Reality (VR) in educational methodologies, noting their role in facilitating immersive learning experiences that effectively simulate real-life tasks. Interestingly, Cakici et al. (2023) identify demographic influences, particularly gender, affecting technology adoption in educational settings. Collectively, these studies underline the transformative potential of AR and XR technologies in enriching architectural design education by improving cognitive skills and engagement while also highlighting the need to consider demographic factors in technology implementation.

Conclusion

The systematic literature review identified a total of 1155 articles across ScienceDirect, Scopus, and the Web of Science databases related to augmented reality (AR) technologies in architectural design education. After applying inclusion and exclusion criteria, ten articles remained for analysis.

Among the included studies, several key themes emerged regarding the integration and impact of AR technologies in architectural design education:

- Most studies highlighted AR technologies' positive influence on various components of design studio education, particularly in fostering experiential learning opportunities. Through AR, students could engage in immersive experiences that facilitated a deeper understanding of architectural concepts and design principles. Studies such as Darwish et al. (2021) and Hartless et al. (2021) demonstrated that utilizing XR technology, including AR, significantly improved students' spatial cognitive skills and tacit knowledge acquisition. These findings suggest that AR technologies can potentially enhance students' spatial perception and design proficiency.
- Some studies, like Spitzer et al. (2021), proposed decision-making frameworks for selecting appropriate XR technologies in architectural education. These frameworks aim to guide educators in integrating AR technologies effectively into curriculum design and instructional practices.
- Cakici et al. (2021) observed a strong correlation between gender and the utilization of computer programs in architectural design, highlighting potential disparities in technological proficiency among students.

While the studies underscored the promise of integrating AR technologies in architectural design education, they also acknowledged the need for further exploration to address challenges and optimize these technologies' full potential. The review emphasized the importance of comprehensive evaluation and highlighted both the advantages and limitations of adopting AR in educational settings.

In summary, the literature synthesis revealed a growing interest in integrating AR technologies in architectural design education, with studies demonstrating positive impacts on learning outcomes, spatial abilities, and engagement. However, future research endeavors should address existing gaps, refine pedagogical approaches, and maximize AR technologies' benefits to ensure their effective integration and sustainable implementation in educational contexts.

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