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A THEMATIC REVIEW ON ARTIFICIAL INTELLIGENCE (AI), VIRTUAL REALITY (VR), AND AUGMENTED REALITY (AR) IN ARCHITECTURE EDUCATION

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ABSTRACT

In the current era, the popularity of Artificial Intelligence (AI) and immersive learning tools, such as Virtual Reality (VR) and Augmented Reality (AR) applications, has been growing in the arts and design sector in recent years. Such technologies in higher education are revolutionizing traditional pedagogical approaches, particularly in architectural education, where it is crucial to comprehend spatial qualities, forms, and structures. Numerous tools are publicly available, both commercial and open source, offering a chance to convert, model, experience, and visualize the form or the images of the designs. Despite the popularity, there is an absence of articles exploring the trends in the applications of those tools in architectural education. Therefore, this thematic review paper (TR) aims to synthesize literature from 2018 to 2024 on keywords such as AI, AR, VR, and architectural education from SCOPUS and MENDELEY databases. The result of this thematic review reveals five themes: architectural theories understanding, ideas generating, space and form exploration, students' behavior, and technical exploration. The findings provide valuable insights for researchers and practitioners who are interested in the application of AI, VR, and AR within the field of architectural education.

1. INTRODUCTION

With the rapid evolution of information and communication technology, significant changes and improvements have become essential across various sectors, including education. ICT is regarded as one of the most crucial tools for enhancing learning, offering new ways to engage students, and enriching educational experiences (Sampaio et al., 2010). In architectural education, the primary goal is to equip students with the knowledge and skills necessary for a successful architectural career. Architecture and interior design especially require a delicate balance between functionality and aesthetics. Architects must consider both the practical purpose of a structure and its visual form to meet the diverse needs of their clients (Kumar & Janardhan, 2023).

As students advance in their architectural education, it becomes essential for them to engage with experiences and environments that extend beyond the conventional classroom setting. Thus, architectural education should oscillate between indoor and outdoor learning spaces to enhance understanding and engagement (Ummihusna & Zairul, 2022a). As early as 2014, technologies such as virtual reality (VR) demonstrated their potential in applying 3D modeling techniques to develop models that are related to construction processes. These models have been particularly useful in civil and construction engineering disciplines (Sampaio & Martins, 2014). The adoption of VR technologies in architectural education has shown the capability to achieve superior results compared to traditional teaching methods (Bashabsheh et al., 2019). Similar to augmented reality (AR), mixed reality (MR), and game technology. These technologies have been used across various branches of architectural studies, including design communication, architectural design, architectural technology, building construction science, and the history and theory of architecture (Ummihusna & Zairul, 2022b).

Parallel to VR, the rapid integration of Artificial Intelligence (AI) tools, specifically text-to-image generators, has profoundly impacted various domains, including architectural studies. The fast-paced evolution of AI technologies, such as diffusion-based AI art platforms, offers unique solutions for understanding and developing architectural concepts, particularly in the fields of architectural history and theory (Fareed et al., 2024; Sadek, 2023). These platforms can generate visually compelling images from simple text descriptions, aiding designers and architects in enhancing and accelerating their creative processes while maintaining innovation (Wang et al., 2022).

Furthermore, the Covid-19 pandemic has significantly disrupted

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the learning experience. The Royal Institute of British Architects (RIBA) Covid-19 Student Survey 2020 indicates that only specific parts of the architecture curriculum are suitable for online teaching and learning, highlighting the need for crucial planning for a digital future (Royal Institute of British Architect, 2020). Therefore, the objective of this paper is to thematically access the usage of AI, VR, and AR in various architectural education sections that have been discussed in the AI, VR, and AR publications from the year 2018 to 2024 through the following research question:

RQ: What are the current trends in Artificial intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) tools related to architecture and interior design education being discussed from the year 2018 to 2024?

2. MATERIALS AND METHODS

The term thematic review using ATLAS.ti is the tool that has been introduced by (Zairul, 2021b, 2021a; Zairul et al., 2023; Zairul & Zairul, 2020). This method has also been protected by copyright, under the registration number CRLY2023W02032 (Zairul, 2023). TR is utilized because the methodology of this study involves applying a thematic analysis procedure in conducting a literature review. Clarke and Braun (2013) define thematic analysis as identifying the pattern and constructing themes over thorough reading on the subject.

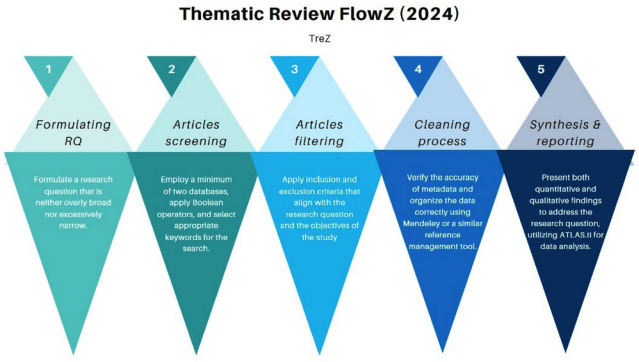


***Figure 1**: Thematic Review FlowZ 2024. (TreZ)*

The first step in the thematic review process involves formulating a research question **(Define RQ)** *(see previous section)*. This step emphasizes the importance of creating a question that is appropriately scoped—not overly broad nor excessively narrow. This ensures that the research question is manageable and focused, setting a clear direction for the subsequent steps. Next, articles are screened for relevance **(Screen)** *(table 1)*. This involves employing a minimum of two databases for comprehensive coverage; Boolean operators are used to refine the search process, and appropriate keywords are selected to identify relevant articles. This phase ensures that a broad yet precise range of literature is considered **(Filter)** *(figure 2)*. The fourth phase focuses on the cleaning process **(Finalize)**. This step involves verifying the accuracy of metadata and organizing the data correctly. Tools such as Mendeley or similar reference management software are utilized to manage the data efficiently. This ensures that the data is reliable and well-organized for analysis. The final step is synthesis and reporting **(Synthesis)**, in this phase, both quantitative and qualitative findings are presented to address the research question. Data analysis tools such as ATLAS.ti are utilized to analyze the data comprehensively. This step involves compiling the findings into a coherent report that answers the research question and provides valuable insights.

Overall, the Thematic Review FlowZ (2024) provides a systematic approach to conducting a thematic review, ensuring thoroughness and accuracy at each stage of the process. The following step is to identify the pattern and construct a category to understand the trend of AI and Immersive learning publications in architectural education. The tenets of the research are to analyze and interpret the findings for the recommendation of future research in AI and Immersive learning in architectural education subject. The selection of literature was performed according to several selection criteria: 1) publication from 2018- 2024, 2) Have at least keyword(s) AI or VR or AR and AR, 3) Focus on architectural education, including designing process, modeling, and visualization.

***Table 1:** Search strings from Scopus and Mendeley*

SCOPUS	TITLE-ABS-KEY ((ai AND architecture OR interior AND design AND education) OR (“artificial intelligence” AND architecture OR interior AND design AND education) OR (vr AND “architectural education”) OR (ai AND “architectural education”)) AND PUBYEAR > 2016 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, “ar”)) AND (LIMIT-TO (PUBSTAGE, “final”)) AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (OA, “all”))	78 results
Mendeley	TITLE: (AI AND “architectural education”) OR (VR AND “architectural education”) OR (AR AND “architectural education”) Year: 2018 TO 2024, Doc Type: Journal, Access type: Open Access	21 results

The literature review was conducted by searching two major academic databases Mendeley and SCOPUS engines were used to find peer-reviewed journals relevant to the given topic. In SCOPUS, the search was defined with the keywords “artificial intelligence, “ virtual reality,” augmented reality,” and “architectural education”. In the title, abstract, and keywords **(TITLE-ABS-KEY)**, targeting publications from 2019 to 2024, and restricted to academic articles in English that were open-access **(LIMIT-TO (DOCTYPE, “ar”))** AND **(LIMIT-TO (PUBSTAGE, “final”))** AND **(LIMIT-TO (LANGUAGE, “English”))** AND **(LIMIT-TO (OA, “all”))**. 78 articles from Scopus were found in the preliminary search. In contrast, the search conducted in Mendeley was more extensive, employing the same keywords across all fields without imposing specific field restrictions, and targeting only open-access articles in English. This method resulted in 21 findings. The discrepancy in the number of articles obtained from each database likely highlights differences in their indexing scope, journal coverage, and search algorithm details, offering a varied collection of articles for review.

In this thematic review, specific search terms were used to carefully plan and carry out a process to find relevant literature from two main academic databases, SCOPUS and Mendeley. We describe the steps taken to ensure a strong selection of studies that improve the accuracy and dependability of the review findings (see Table 1).

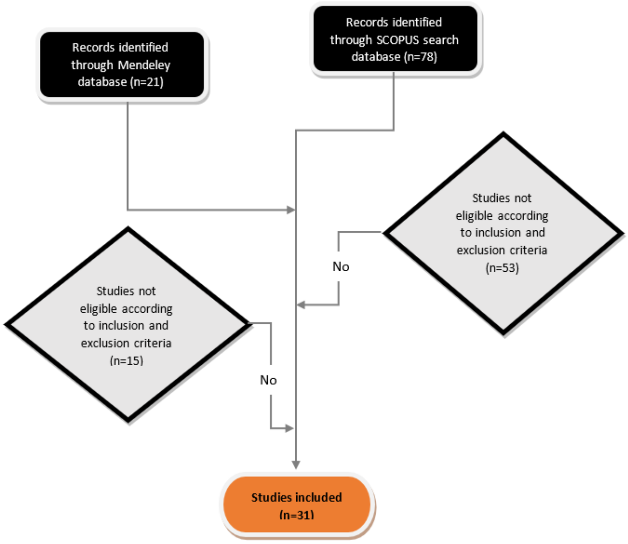


***Figure 2**: Inclusion and exclusion criteria*

The search started with carefully crafted queries designed to meet the objectives of this study. These queries were applied to the SCOPUS and Mendeley databases, resulting in the identification of 78 records from SCOPUS and 21 records from Mendeley. The next step is to identify and remove duplicate entries to maintain the uniqueness of each record in subsequent analyses. However, 68 articles were removed due to their premature results and anecdotes or did not discuss AI in architectural education. Furthermore, many of the articles were discovered to be incomplete or to be completely inaccessible, with broken links, overlapped content, retracted papers, and insufficient information. As a result, the final paper has been reviewed down to 31 articles (Table 1).

The articles were uploaded in the ATLAS.ti 9 as primary documents, and then each paper was grouped into 1) author; 2) issue number; 3) periodical, 4) publisher, 5) volume, and 6) year of publication. In doing so, the articles can be analyzed according to the year it was published and what is the discussion pattern according to the year. The total number of articles that have been finalized into the final documents in the ATLAS.ti 9 is 31 documents. Only English papers, open-access, and full articles were selected.

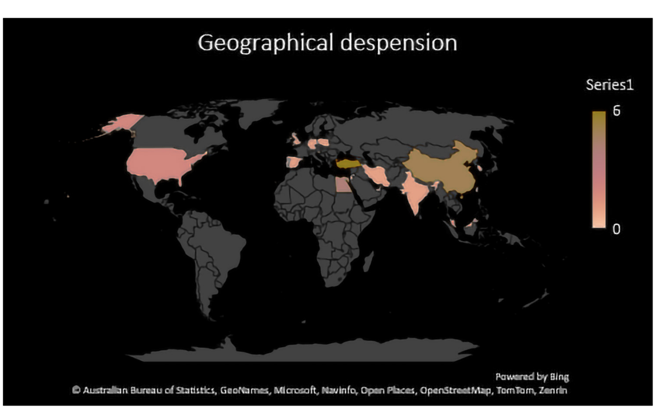


***Figure 3:** Paper breakdown according to the year of publication*

The provided geographical dispersion map offers a compelling visual representation of data distribution across various global regions during the period of the study. The map employs a color gradation scale from 0 to 6 representing the total number of articles, where lighter shades represent lower values and darker shades signify higher values. This visualization effectively highlights regions with varying intensities of the measured variable, providing valuable insights into global patterns and trends. The map indicates that certain regions exhibit high levels of the measured variable, particularly in parts of Asia and North America. Notably, China, Turkey, Egypt, and the United States stand out with the darkest shades, suggesting a significant concentration of the presence of AI, VR, and AR in architectural education in these areas. This could be indicative of high population density, economic activities, technological development, or other relevant factors that are prevalent in these countries. Several regions in Europe and Asia, especially Central and Eastern Europe, display moderate levels of intensity. The presence of moderate values in these areas may point to a balanced distribution of the measured variable, possibly indicating stable economic activities, moderate population densities, or consistent technological development. These regions, while not as prominent as the high-intensity areas, still play a significant role in the global distribution of the measured variable.

The geographical dispersion map serves as a powerful tool for understanding the distribution of key variables on a global scale. The high-intensity regions highlight areas of significant presence, which could be crucial for businesses, policymakers, and researchers aiming to target or understand these regions better. The moderate-intensity areas provide a balanced view, indicating regions with stable conditions that might be ripe for further development or investment. The low-intensity regions, on the other hand, point to potential areas of growth, suggesting opportunities for development initiatives, resource allocation, or targeted interventions to enhance the measured variable's presence.

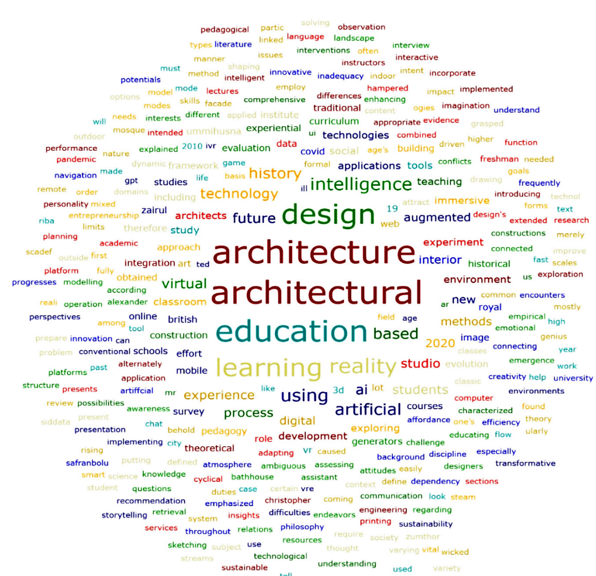


***Figure 4:** Word cloud generated from 31 articles*

The word cloud highlights how advanced methodologies and modern technology are integrated into architectural education. Key themes include design, the learning process, architecture, and education. Terms such as artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) draw attention to how technology is being used to enhance the educational process. The STEAM approach, which integrates Science, Technology, Engineering, Arts, and Mathematics to offer a comprehensive educational experience, is one of the key approaches. Another important aspect of education is experiential learning, which emphasizes deeply engaging, hands-on approaches for pupils. Words such as immersive and interactive emphasize how captivating modern teaching methods and resources are. Specific tools, such as online systems and 3D modeling, are recognized for their significance in today's architectural education, supporting active learning and communication. The word cloud also emphasizes the significance of sustainability, the environment, and history in the curriculum. Comprehending the architectural history, integrating sustainable design ideas, and taking the environment into account are essential elements. Creativity and innovation are key themes, indicating a focus on fostering inventive thinking and preparing students to tackle complex design challenges with new solutions.

3. RESULTS AND DISCUSSIONS

This thematic review (TreZ) presents a five-year overview of advanced technologies and digitalization in architectural education. The selected articles highlight the significant role digital technologies such as AI, VR, and AR play in higher education, specifically in the field of architecture. Notably, the articles reveal the various roles of AI, VR, and AR in architectural education, emphasizing their transformative potential in various educational themes. The study examined detailed diagrams and related studies, highlighting how these technologies facilitate creative idea generation, such as those by (Tong et al., 2023) and (Sadek, 2023), enhance students' behavior towards digital tools as utilized by (Bai & Li, 2021) and (Cao et al., 2023)yielding 158 valid responses. The investigation aimed to gauge students' familiarity with recent AI advancements (e.g., ChatGPT, Stable Diffusion, Midjourney, and enable comprehensive technical exploration as mentioned by (Abdullah et al., 2020). AI, VR, and AR not only modernize architectural pedagogy but also provide immersive, interactive learning experiences that significantly improve students' technical skills and creative capabilities.

Primarily the articles that are included discuss the advantages and difficulties of incorporating AI, VR, and AR into architecture education. For example, Cao's (2023)yielding 158 valid responses. The investigation aimed to gauge students' familiarity with recent AI advancements (e.g., ChatGPT, Stable Diffusion, Midjourney pivotal study, which examines students' attitudes and awareness regarding AI applications, provides an important realization, i.e., although a significant portion of students are aware of AI's potential in architectural design, many have yet to make use of these tools. This discrepancy between knowledge and actual application points to a major area where architecture education has to improve, highlighting the necessity of increasing practical instruction and incorporating AI technologies into the curriculum. Furthermore, Dickinson (2020)or a solution is derived from a process involving the people and circumstances of the problem. The first way is object focused and is celebrated in architectural criticism and journalism. It is the way of the salvational Genius, whose personal insight pierces all preconceptions and launches into innovation. This operational model is called the architectural canon. The second way, working through a process, is how the rest of us grapple with any issue. The power of Christopher Alexander's life is not about the distillation of a personal perspective (the profession's stereotypical Genius model discussed Christopher Alexander's extraordinary life mission that emphasizes the importance of human skills where we see, hear, think, and offer what technology cannot.

This study adds significantly to our knowledge of modern technological practices in the context of architectural education. The research offers a thorough overview of how various innovative tools and systems, such as AI, VR, and AR, are being incorporated into architectural education through the thematic review process. This helps to improve theory understanding, build creativity in idea generation, and investigate real-world applications.

3.1. Quantitative reporting

The following Table 2 provides a comprehensive categorization of research articles focusing on the different aspects of artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) tools related to architecture and interior design education. The themes highlight the diverse approaches and topics that are covered by researchers, from architectural theories understanding to ideas generating, space and form exploration, students' behavior, and technical exploration. The majority of articles on AI, VR, and AR reflect the critical importance of these tools in improving architectural education. The significant focus on developing space and form further emphasizes the need for long-term assessment to ensure that skills development, creativity, and career trajectories are achieved. Each theme contributes uniquely to advancing the understanding and implementation of these tools in architecture education, addressing both theoretical and practical aspects.

Table 2: *Author vs theme*

	Theme 1: Architectural Theories Understanding	Theme 2: Ideas generating	Theme 3: Space and Form Exploration	Theme 4: Students' Behavior	Theme 5: Technical Exploration
(Şahbaz, 2020)	/	-	-	-	-
(Fareed et al., 2024)	/	-	/	-	-
(Avsec et al., 2022)	-	-	-	-	/
(Tong et al., 2023)	-	/	-	-	-
(Caliskan, 2023)	-	-	-	/	-
(Dickinson, 2020)	/	-	-	-	-
(Yang & Liu, 2022)	-	-	-	/	-
(Sun et al., 2019)	-	-	/	-	-
(Cao et al., 2023)	-	/	-	/	-
(Bai & Li, 2021)	-	-	-	/	-
(Li et al., 2022)	-	-	/	-	-
(Weber et al., 2022)	/	-	-	-	-
(Raposo Grau & Paredes Maldonado, 2023)	-	-	-	-	/
(Prasetyo & Habibie, 2022)	-	-	-	-	/
(Almaz et al., 2024)	-	-	/	-	/
(Chien & Yao, 2020)	-	-	-	-	/
(Sadek, 2023)	-	/	-	-	-
(Zakariya et al., 2023)	-	-	/	-	-

	Theme 1: Architectural Theories Understanding	Theme 2: Ideas generating	Theme 3: Space and Form Exploration	Theme 4: Students' Behavior	Theme 5: Technical Exploration
(Agirachman et al., 2022)	-	-	/	-	/
(Bashabsheh et al., 2019)	-	-	-	-	/
(Kumar & Janardhan, 2023)	-	-	-	-	/
(Basarir, 2022)\	-	-	/	-	/
(Chun, 2021)	-	-	/	-	-
(Ummihusna & Zairul, 2022a)	-	-	/	-	-
(Hamid Khalili, 2023)	/	-	/	-	-
(Banaei et al., 2020)	/	-	/	-	-
(Alp et al., 2023)	-	-	/	-	-
(Abdullah et al., 2020)	-	-	-	/	-
(Elsayed et al., 2020)	-	-	/	-	-
(Makaklı, 2019)	/	-	-	/	-
(Darwish et al., 2023)	-	-	/	/	-

3.2. QUALITATIVE REPORTING

The diagram (Figure 5) presents a thematic analysis of current trends in the use of Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) in architecture and interior design education from 2018 to 2024. It centers around five key themes: Architectural Theories Understanding, Ideas Generating, Space and Form Exploration, Students' Behaviour, and Technical Exploration. Each theme highlights the frequency of general contributions (G) with no density contributions (D) noted. "Space and Form Exploration" is the most discussed theme with 14 contributions, indicating significant interest on how VR and AR facilitate interactive exploration of architectural spaces. "Technical Exploration" follows with nine contributions, showing how these technologies aid in the technical aspects of architecture education. Both "Architectural Theories Understanding" and "Students' Behaviour" have seven contributions each, reflecting their roles in enhancing theoretical knowledge and influencing student engagement. "Ideas Generating", with three contributions, focuses on the creative process facilitated by these tools. This analysis underscores the broad impact and diverse applications of AI, VR, and AR in transforming architectural education.

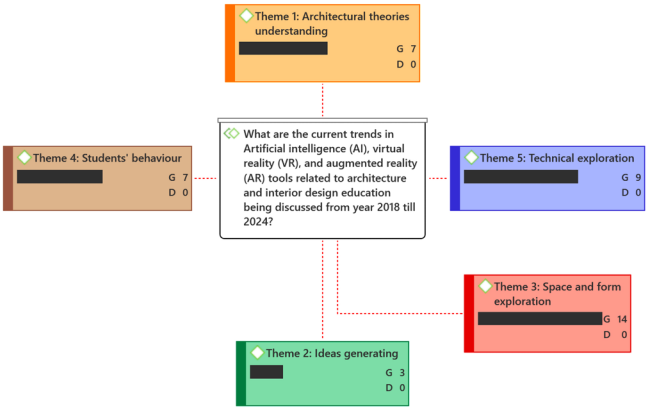


Figure 5: *The themes to answer RQ*

3.2.1 Theme 1: Architectural Theories Understanding

The integration of cutting-edge technologies such as Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) is revolutionizing architectural education, particularly in the realm of understanding architectural theories. Traditionally, architectural education has relied heavily on two-dimensional drawings and physical models to convey complex theoretical concepts. However, the advent of AI, VR, and AR provides students with unprecedented tools to visualize, analyze, and interact with architectural designs and theories in dynamic, immersive ways. AI facilitates advanced computational analyses and design optimizations, VR offers immersive, three-dimensional experiences that bring theoretical concepts to life, and AR allows for the seamless blending of digital models with the physical environment.

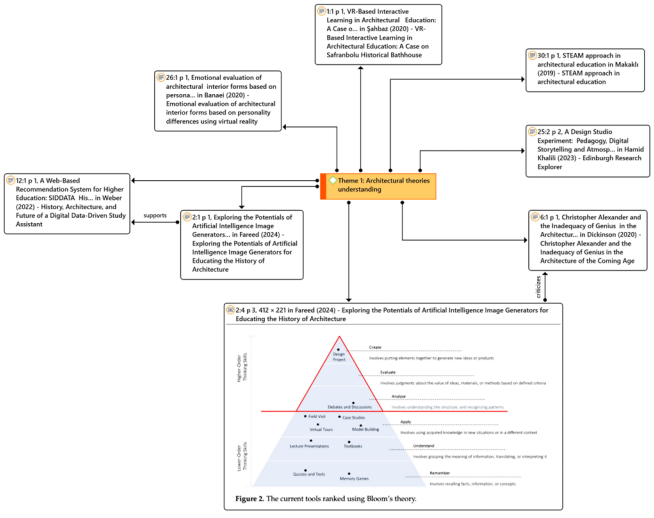


Figure 6: *Theme 1 (Architectural Theories Understanding)*

Şahbaz (2020) made a noteworthy contribution to the field of architectural education by investigating VR-based interactive learning through a case study involving the Safarnbulo Historical Bathhouse. This study emphasizes how virtual reality may provide lifelike historical reconstructions, giving pupils a concrete link to theoretical ideas and architectural history. In this setting, virtual reality (VR) offers a more dynamic and captivating educational experience that can greatly improve students' understanding and recall of architectural history. Similarly, Banaei (2020) examined the emotional evaluation of architectural interior forms based on personality differences using virtual reality. This study highlights the psychological impact of architectural spaces and how VR can be tailored to provide personalized educational experiences. By considering individual emotional responses, VR can create more effective learning environments that cater to the diverse needs of students, enhancing their overall academic experience.

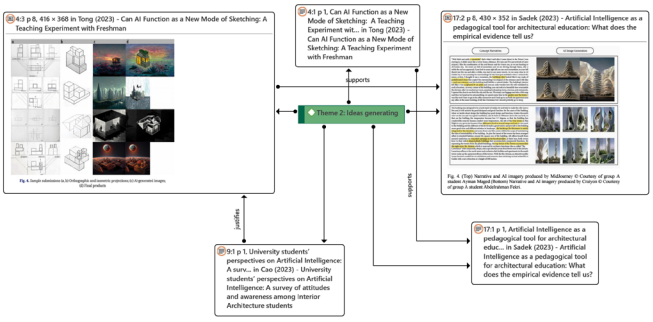
On the aspects of historical architecture and architectural theories, Fareed (2024) has explored the potential of AI image generators for educating about the history of architecture. AI tools can create realistic visualizations of historical sites, offering students detailed and accurate representations of architectural evolution and theories. This use of AI highlights its potential in providing comprehensive visual aids that can significantly enhance the learning experience. This study was also supported by Weber (2022) by developing a

web-based recommendation system for higher education, named SIDDATA (Study, Digital Storytelling, Interactive, Design, Data, and Architectural Assistant). This system integrates AI to personalize learning experiences, helping students navigate complex architectural theories more efficiently. The SIDDATA system exemplifies how AI can be used to create adaptive learning environments that meet individual student needs.

In contrast to the potential of AI, VR, and AR in architectural education, Dickinson (2020)or a solution is derived from a process involving the people and circumstances of the problem. The first way is object focused and is celebrated in architectural criticism and journalism. It is the way of the salvational Genius, whose personal insight pierces all preconceptions and launches into innovation. This operational model is called the architectural canon. The second way, working through a process, is how the rest of us grapple with any issue. The power of Christopher Alexander's life is not about the distillation of a personal perspective (the profession's stereotypical Genius model discussed Christopher Alexander's extraordinary life mission, which emphasizes the importance of human skills where we see, hear, think, and offer what the technology cannot. Ultimately, there are just two methods of production. First, both things are defined as objects by virtue of their inherent nature, and thus are entirely produced inside and according to the methods of genius. The second method of creation is a process of listening to and considering every "why" that is accessible to each and every one of us. The polymath Christopher Alexander provides a relationship between our environment and our ideals that no conventional genius caricature can understand. Summatively, the diagram (Figure 6) illustrates a comprehensive approach to understanding architectural theories through the integration of AI, VR, and AR technologies. Each study and methodology contribute unique insights into how these technologies can enhance the various aspects of architectural education, from historical reconstructions and emotional evaluations to personalized learning experiences and digital storytelling. This thematic analysis underscores the transformative potential of AI, VR, and AR in revolutionizing architectural education and theory understanding.

3.2.2 Theme 2: Ideas generating

Traditionally, the process of ideation in architecture relied on sketches, physical models, and two-dimensional drawings. However, the integration of these advanced technologies is providing students with innovative tools to enhance their creative process. AI offers powerful algorithms that can analyze vast datasets, suggest design optimizations, and inspire new forms and structures. VR immerses students in a fully interactive, three-dimensional environment where they can experiment with and visualize their ideas in real time. AR overlays digital information onto the physical world, enabling students to explore and modify their designs within the context of existing environments. By leveraging AI, VR, and AR, architectural education is fostering a more dynamic and exploratory approach to idea generation, equipping students with the skills to push the boundaries of traditional design methodologies and paving the way



for groundbreaking architectural innovations.

***Figure 7**: Theme 2 (Ideas generating)*

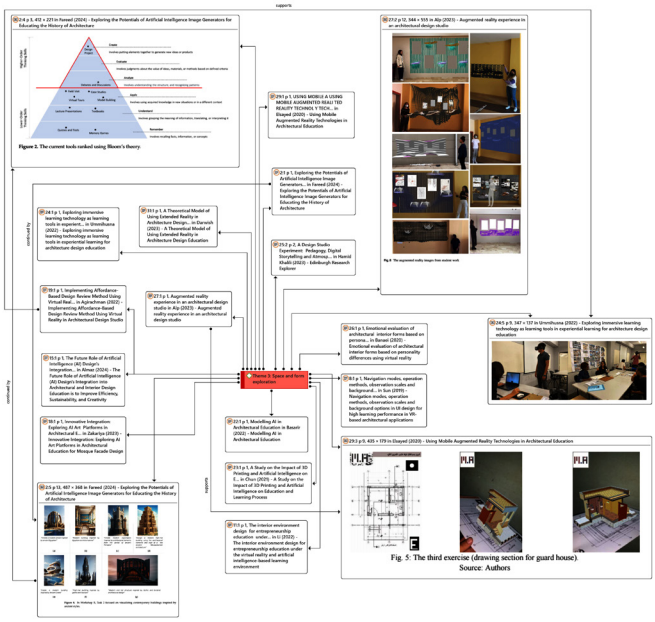
Through a teaching experiment with freshmen, Tong (2023) investigates whether AI may serve as a novel sketching tool. Sample submissions displaying orthographic and isometric projections, AI-generated images, and final deliverables are used to highlight the study's findings. This study lends credence to the idea that AI can improve creative processes in architectural drawing, helping students to better effectively conceptualize complex ideas. Furthermore, Sadek (2023) offers research findings on AI as a teaching tool for architecture education, which strengthens this theme further. Students who used platforms such as MidJourney and Craiyon created the narratives and AI graphics were included in the research. The results indicate that artificial intelligence (AI) may greatly support the creative process, enabling the students to produce original design concepts and investigate architectural forms outside of the box. The actual data demonstrates how AI can improve learning outcomes and promote a more in-depth comprehension of architectural concepts.

The approach of using advanced technology tools such as AI, VR, and AR to generate various ideas is further supported by Cao (2023) yielding 158 valid responses. The investigation aimed to gauge students' familiarity with recent AI advancements (e.g., ChatGPT, Stable Diffusion, Midjourney and his exploration of the perspectives of interior architecture students on artificial intelligence (AI) technologies and their potential impact on future career prospects. The findings revealed a limited awareness among students regarding cutting-edge AI technologies, alongside concerns about the potential negative impact of AI on employment opportunities within the interior design industry. The insights from this research provide valuable justification that by equipping students with the necessary skills and knowledge, institutions can better prepare them for a design industry that is increasingly influenced by AI-driven transformations. Taken as a whole, these studies show how AI can revolutionize the way that ideas are generated in architectural education. Educators may provide students with more engaging and dynamic learning opportunities by incorporating AI tools, which will encourage students' creativity and innovation. The figure (Figure 7) highlights the various advantages of AI in design and architectural education by simply capturing the connections between these contributions.

3.2.3 Theme 3: Space and Form Exploration

The study of space and form in the growing field of architecture education is rapidly changing as a result of the incorporation of innovative technologies such as Augmented Reality (AR), Virtual Reality (VR), and Artificial Intelligence (AI). These advanced

resources are transforming how students understand, create, and engage with architectural ideas. They offer never-before-seen possibilities for creative problem-solving and immersive learning. AI offers powerful analytical capabilities, enabling students to rapidly generate and evaluate complex design variations. VR immerses students in fully realized virtual environments, allowing them to experience and manipulate architectural forms in real time. Meanwhile, AR overlays digital information onto the physical world, enhancing contextual understanding and facilitating real-time design adjustments. Together, these technologies enhance the pedagogical approaches in architectural education and equip future architects with the skills and insights that are needed to navigate and shape an



increasingly complex built environment.

Figure 8: *Theme 3 (Space and form exploration)*

The third theme, "Space and Form Exploration," looks at how new ways to explore space and form are made possible by AI, AR, and VR technologies, and how this affects architectural education. Fareed (2024) explores how AI image generators may be used to teach architectural history. By utilizing these resources, students may bridge the gap between conventional teaching strategies and contemporary technology by better seeing and comprehending historical architectural forms. In this case, AI application improves understanding and memory of architectural history. In correspondence, Basarir (2022)part of the domain knowledge and hard skills become either irrelevant or insufficient by the time the students graduate. This paper suggests that integrating AI in the architectural design curriculum is beneficial for raising designers' awareness of all areas of architectural design, in the form of input, process, and output. The study views consecutive learning experiences in a continuum and explores the potentials of integrating AI applications and techniques in architectural education, and how architectural design practice may benefit from it. Consequently, it provides insights into how architectural design education may transform itself considering the future impact of AI on the Architecture Engineering Construction (AEC further discusses modeling AI in architectural education, stressing the significance of integrating AI tools to enhance design processes and outcomes. This study gives validity to the idea that AI can simplify difficult design assignments so that students can concentrate on the more aesthetic elements of architecture.

Exploring spaces and forms is not limited by AI methods. For instance, Elsayed (2020) emphasizes the use of mobile augmented reality (AR) technologies in architectural education. This study highlights the practical implementation of AR tools, demonstrating how they can transform architectural design studios. Notably, by integrating AR into the learning environment, students gain hands-on experience in manipulating space and form, which fosters a deeper understanding of architectural concepts. Similarly, Alp (2023) presents augmented reality experiences in an architectural design studio, showcasing various student projects that leverage AR for creative exploration and design development. Furthermore, Agirachman (2022) focuses on implementing affordance-based design review methods using VR, showcasing its application in architectural design studios. This approach allows students to engage with their designs in a virtual space, facilitating a better understanding of spatial relationships and design implications. Ummihusna and Zairul (2022a) have also explored immersive learning technologies, emphasizing their role in experiential learning for architecture space and form. These technologies support active learning and enhance the architectural experience for students.

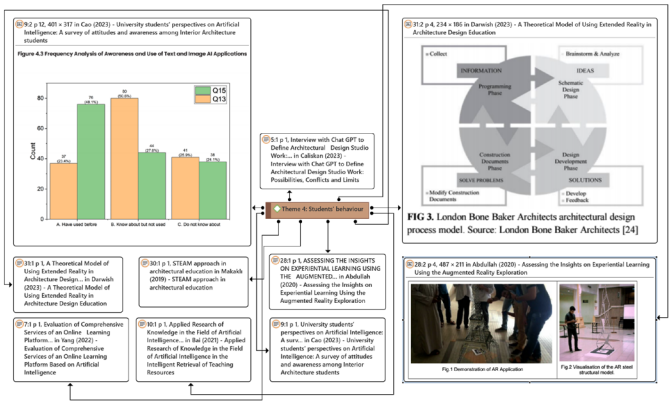
To achieve high learning performance in VR-based architectural applications, Sun (2019) investigates navigation modes, operation techniques, observation skills, and backdrop possibilities in user interface design. This study emphasizes how crucial a well-thought-out user interface is to improving the educational process by empowering students to successfully navigate and engage with virtual environments. Furthermore, Li (2022)with the rapid growth of artificial intelligence (AI looks at the interior environment design of entrepreneurial education, emphasizing the ways in which immersive technologies and artificial intelligence may produce dynamic, interactive learning environments. Together, these studies show how AI, AR, and VR technologies have a significant impact on students' exploration of space and form in architecture education. With the aid of these cutting-edge resources, teachers may provide their students with engaging and dynamic learning opportunities that will improve their capacity to imagine and create creative architectural solutions. The diagram (Figure 8) effectively captures the interconnections between these studies.

In conclusion, Theme 3: "Space and Form Exploration" demonstrates the transformative potential of AI, AR, and VR technologies in the realm of architectural education. Through a variety of studies, this theme highlights how these advanced tools are reshaping the ways students explore and understand spatial relationships and architectural forms; for instance, from AI image generators to mobile AR and VR applications. Moreover, as discussed by Sun (2019), the importance of well-designed user interfaces in VR environments underscores the need for intuitive navigation to maximize learning outcomes. Additionally, the integration of AI and immersive technologies in educational frameworks fosters collaborative and engaging learning environments. The role of immersive learning technologies in experiential education, as explored by Ummihusna

and Zairul (2022b), and the efficiency brought by AI modeling in design processes, as discussed by Basarir (2022)part of the domain knowledge and hard skills become either irrelevant or insufficient by the time the students graduate. This paper suggests that integrating AI in the architectural design curriculum is beneficial for raising designers' awareness of all areas of architectural design, in the form of input, process, and output. The study views consecutive learning experiences in a continuum and explores the potentials of integrating AI applications and techniques in architectural education, and how architectural design practice may benefit from it. Consequently, it provides insights into how architectural design education may transform itself considering the future impact of AI on the Architecture Engineering Construction (AEC, further illustrate the profound impact of these technologies on architectural education. Collectively, these studies underscore the significance of leveraging AI, AR, and VR to enhance the educational experiences of architecture students, fostering innovation, creativity, and a deeper understanding of space and form.

3.2.4 Theme 4: Students' behavior

Students in architecture education are increasingly recognizing the value of artificial intelligence (AI) in their field. Many students view AI as a tool to enhance their design processes, allowing for more efficient and innovative solutions. They are actively engaging with AI-driven softwares to analyze complex data sets, optimize building designs, and simulate environmental impacts. This proactive behavior reflects their understanding of AI's potential to streamline workflows and foster creativity (Bai & Li, 2021). However, some students may exhibit hesitation or resistance due to a lack of familiarity with the technology or concerns about AI's implications on traditional architectural practices. Overall, the trend indicates a growing acceptance and curiosity among architecture students toward integrating AI into their educational and professional pursuits (Cao et al., 2023)yielding 158 valid responses. The investigation aimed to gauge students' familiarity with recent AI advancements



(e.g., ChatGPT, Stable Diffusion, Midjourney.

Figure 9: *Theme 4: (Students' behavior)*

The diagram on Theme 4: "Students' Behavior Towards AI, VR, and AR in Architecture Education" offers an extensive examination of how students perceive and interact with these cutting-edge technologies within their educational frameworks. A pivotal study by Cao (2023)yielding 158 valid responses. The investigation aimed to gauge students' familiarity with recent AI advancements (e.g., ChatGPT, Stable Diffusion, Midjourney surveys students' attitudes and awareness toward AI applications, revealing a critical insight: while a substantial number of students are aware of AI's potential in architectural design, many have yet to utilize these tools. This gap between awareness and practical application highlights a significant area for improvement in architectural education, emphasizing the need for more hands-on training and integration of AI technologies into the curriculum. Darwish (2023) adds to this argument by offering a theoretical framework for utilizing extended reality in architectural design education. This concept describes a thorough, methodical procedure that students can follow for integrating VR and AR into the educational process. Information gathering, brainstorming, schematic design, and development phases are some of its stages. By using this approach, teachers and students can develop an engaging and dynamic learning environment that aids the students in comprehending and visualizing intricate architectural ideas.

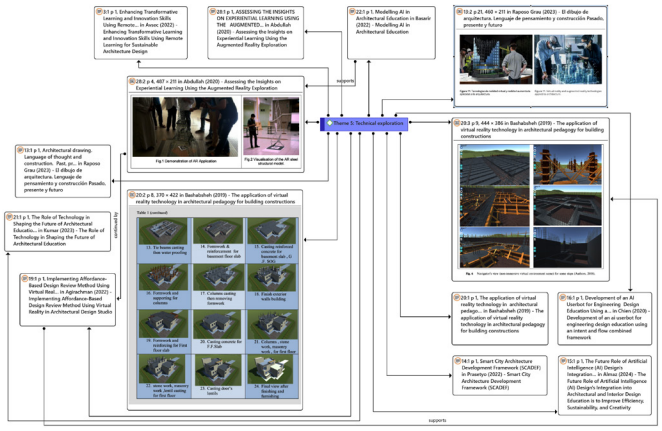
Furthermore, Caliskan (2023) investigates the transformative potential of AI-driven tools such as ChatGPT in architectural design studio settings. The research examines the opportunities, challenges, and constraints of integrating AI into education. AI offers substantial benefits by equipping students with sophisticated analytical tools and innovative ideas, enhancing the design process. Similarly, Abdullah (2020) provides practical insights into the use of augmented reality (AR) for experiential learning in architecture, where students showed high enthusiasm toward learning and exploring the potentialities of the assigned tools. However, the study of Caliskan (2023) also identifies potential conflicts, such as the danger of becoming overly dependent on technology and the necessity of balancing AI insights with traditional design expertise. This balanced perspective emphasizes the need for critical thinking and adaptability amid technological progress.

All in all, the behavioral analysis of students reveals a mix of enthusiasm and apprehension toward AI, VR, and AR technologies. While there is a strong interest in these technologies, practical usage, and comprehensive understanding remain areas for further development. The studies collectively suggest that educational institutions must not only incorporate advanced technologies into their curriculum but also provide adequate training and resources to ensure that students can fully leverage these tools. By doing so, architecture education can be significantly enhanced, fostering innovation and creativity among future architects and preparing them for future challenges.

3.2.5 Theme 5: Technical Exploration

The incorporation of Artificial Intelligence (AI), Virtual Reality (VR), and Augmented Reality (AR) technology in architecture education has demonstrated considerable potential in augmenting students' comprehension of construction systems and exploration of design ideas. Virtual reality technology, such as the SimYA project (Şahbaz, 2020), offer immersive experiences that facilitate learning by doing and experiencing in architectural education, particularly in construction studio settings. Similarly, AR technologies, enable collaborative learning strategies that enhance interdisciplinary education in architecture, engineering, and construction (AEC) fields. Also, AI tools such as ChatGPT can assist students by

generating design suggestions, optimizing spatial layouts, and predicting structural performance. AI can also help in simulating various construction scenarios, allowing students to foresee potential issues and learn how to address them effectively. This enhances their technical skills and prepares them for real-world challenges, developing them to be more competent and innovative architects. These technologies provide students with interactive and engaging platforms to explore complex construction concepts and design



principles.

Figure 10: *Theme 5 (Technical exploration)*

The interconnected studies and articles present a multifaceted view of the current landscape and future potential of AI, VR, and AR in architecture education. In terms of augmented reality, Abdullah (2020) assesses the insights on experiential learning. This study showcases practical applications of AR in architectural education, allowing students to visualize and interact with structural models in real time. The immersive experience provided by AR helps the students to understand complex construction processes and spatial relationships, which are critical for architectural design. By engaging with these virtual models, students can better grasp the intricacies of building constructions, thereby enhancing their technical skills and preparing them for real-world challenges. Similarly, Kumar (2023) emphasizes the role of technology in shaping the future of architectural education, where the integration of AI, VR, and AR into the curriculum is highlighted as a crucial step toward modernizing architectural education. These technologies provide students with advanced tools for design and analysis, facilitating a deeper understanding of architectural principles and construction methods.

Furthermore, Bashabsheh (2019) focuses on the application of virtual reality (VR) technology in architectural pedagogy for building construction. The study emphasizes the effectiveness of VR in creating realistic, non-immersive virtual environments where students can explore various construction stages and techniques. VR simulations offer a hands-on learning experience that traditional methods cannot match, enabling students to experiment with different design solutions and understand their implications in a controlled, risk-free environment. Continued by Agirachman (2022) the study discusses the implementation of an affordance-based design review method using virtual reality. This method allows students to evaluate and refine their design projects in a virtual environment, providing immediate feedback and opportunities for improvement.

Lastly, the future role of artificial intelligence (AI) in architecture education is examined by (Almaz (2024)making it faster, more efficient, and more sustainable. AI serves as a starting point for conversation, allowing architects to interact with data scientists and engineers. The study recommends merging AI into architecture education to improve designers' comprehension of design-related concepts. The future role of architects in AI design and its application raises questions about how AI design will reflect their creativity and architectural touch. AI is revolutionizing the design process by integrating Building Information Modelling (BIM. AI's integration into architectural and interior design education is seen as a means to improve efficiency, sustainability, and creativity. According to the study, AI tools can analyze vast amounts of data to provide insights and optimize design details solutions, helping students develop more knowledge on the technicality of the design. The integration of AI, VR, and AR in architecture education for construction and technical exploration represents a significant advancement in teaching methodologies. These technologies provide students with immersive, interactive learning experiences that enhance their technical skills and prepare them for the complexities of the architecture profession. The studies highlighted in this diagram underscore the transformative potential of these technologies, advocating for their continued adoption and integration into architectural curricula.

4. CONCLUSION

This study explored the integration of advanced technologies such as artificial intelligence (AI), virtual reality (VR), and augmented reality (AR) in architectural education, emphasizing their transformative potential in various educational themes. This article examined detailed diagrams and related studies, highlighting how these technologies facilitate creative idea generation, enhance students' behavior toward digital tools, and enable comprehensive technical exploration. AI, VR, and AR modernize architectural pedagogy and provide immersive, interactive learning experiences that significantly improve students' technical skills and creative capabilities. The theme of idea generation illustrates how AI tools are being utilized to innovate the sketching process, encouraging fresh creative approaches among students. Similarly, the theme of students' behavior revealed the varying levels of awareness and acceptance of AI and AR, showcasing the importance of these tools in fostering a proactive learning environment. In the context of space and form exploration, these technologies were shown to be vital in helping students visualize complex architectural concepts and experiment with various design possibilities in a virtual setting.

The theme of technical exploration has provided a comprehensive view of how VR and AR are used to simulate real-world construction processes, enhancing the students' understanding of building techniques and spatial relationships. By enabling hands-on, risk-free experimentation, these technologies prepare students for the practical challenges they will face in their professional careers. Furthermore, the discussion highlighted the role of AI in providing data-driven insights and optimizing design solutions, thereby promoting efficiency, sustainability, and creativity in architectural education. In summary, the integration of AI, VR, and AR in architectural education represents a significant leap forward

in teaching methodologies. These technologies enrich the learning experience by providing students with advanced tools for design, analysis, and visualization. As architectural education continues to evolve, the adoption and integration of these technologies will be crucial in equipping future architects with the skills and knowledge that are needed to excel in an increasingly digital and complex industry.

5. DISCUSSION AND FUTURE STUDIES

Although this study emphasizes the essential functions that AI, VR, and AR serve in architectural education, there are still a number of areas that need more investigation to improve our comprehension and application of these principles. Future research should focus on the long-term impact of AI, VR, and AR on students' learning outcomes and professional development. Longitudinal studies that track students over several years can provide valuable insights into how these technologies influence their skill development, creativity, and career trajectories as it was mentioned by (Cao et al., 2023)yielding 158 valid responses. The investigation aimed to gauge students' familiarity with recent AI advancements (e.g., ChatGPT, Stable Diffusion, Midjourney. The long-term study shall also explore the potential of fostering collaboration between academia and industry that facilitates the exchange of knowledge and resources, ensuring that educational programs are aligned with the industry's needs and technological advancements.

The students exercise in Bashabsheh (2019), and similarly with Abdullah (2020), focuses on the application of virtual reality (VR) technology in architectural pedagogy for building construction. The studies present a promising opportunity to intersect with different fields such as engineering. However, future research should also explore how AI, VR, and AR can facilitate interdisciplinary learning and collaboration with fields such as urban planning, landscape, and environmental science. Studies should investigate how these technologies can be used to create integrated learning environments that bring together students and professionals from different disciplines to work on complex, real-world projects.

Lastly, Dickinson (2020)or a solution is derived from a process involving the people and circumstances of the problem. The first way is object focused and is celebrated in architectural criticism and journalism. It is the way of the salvational Genius, whose personal insight pierces all preconceptions and launches into innovation. This operational model is called the architectural canon. The second way, working through a process, is how the rest of us grapple with any issue. The power of Christopher Alexander's life is not about the distillation of a personal perspective (the profession's stereotypical Genius model discussed the importance of human skills where we see, hear, think, and offer what technology cannot. This study opens the potential of examining human skills and comparing them with advanced technologies such as AI, VR, and AR. Future research should also examine the ethical implications of using these technologies, including issues related to privacy, data security, and digital equity. Studies should also explore how to address potential social and psychological impacts on students, ensuring that the use of these technologies promotes positive and inclusive learning environments.

6. CONTRIBUTIONS AND BENEFITS OF STUDY

This study makes significant contributions to the understanding of innovative technology practices within the framework of architectural education. By conducting a thematic review, the research provides a comprehensive overview of how various innovative tools and systems such as AI, VR, and AR are being integrated into architectural education to enhance creativity in ideas generating, improve theory understanding, and explore practical solutions.

Notably, this study finds and summarizes trends and patterns in a variety of advanced architecture education systems using a thematic review. Through this method, researchers can see how thoughts come together and how major themes that are involved in enhancing architectural education emerge. Furthermore, the thematic review method aids in identifying gaps in existing literature and practices, providing a guide for future research. By highlighting recurring themes and areas of innovation, this study serves as a valuable resource for researchers, practitioners, and academicians aiming to improve the architectural education journey. The insights that are gained from this thematic analysis can guide the development of new curricula, tools, and teaching methods that take place in architecture and interior design education.

In conclusion, this study significantly enhances the understanding of innovative technology practices within architectural education. By conducting a thematic review, it provides a comprehensive overview of the integration of AI, VR, and AR into architectural education, highlighting their roles in fostering creativity, improving theoretical understanding, and exploring practical solutions. The study identifies and summarizes trends and patterns across various advanced architectural education systems, revealing how ideas are converging and major themes are emerging to enhance educational practices. Additionally, the thematic review method helps identify gaps in existing literature and practices, guiding future research. By highlighting recurring themes and areas of innovation, the study serves as a valuable resource for researchers, practitioners, and academicians who are seeking to improve architectural education. The insights from this analysis can inform the development of new curricula, tools, and teaching methods in architecture and interior design education.

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REFERENCES

Abdullah, F., Kassim, M. H., Sanusi, A. N. Z., & Razak, M. R. A. (2020). *Assessing the Insights on Experiential Learning Using the Augmented Reality Exploration*. *VI*(18), 306–314. https://doi.org/10.47696/adved.202055

Agirachman, F. A., Shinozaki, M., Koerniawan, M. D., & Indraprastha, A. (2022). Implementing Affordance-Based Design Review Method Using Virtual Reality in Architectural Design Studio. *Buildings*, *12*(9), 1–29. https://doi.org/10.3390/buildings12091296

Almaz, A. F., El-Agouz, E. A. E. A., Abdelfatah, M. T., & Mohamed, I. R. (2024). The Future Role of Artificial Intelligence (AI) Design's Integration into Architectural and Interior Design Education is to Improve Efficiency, Sustainability, and Creativity. *Civil Engineering and Architecture*, *12*(3), 1749–1772. https://doi.org/10.13189/cea.2024.120336

Alp, N. C., Yazici, Y. E., & Oner, D. (2023). Augmented reality experience in an architectural design studio. *Multimedia Tools and Applications*, *82*(29), 45639–45657. https://doi.org/10.1007/s11042-023-15476-w

Avsec, S., Jagiełło-Kowalczyk, M., & Żabicka, A. (2022). Enhancing Transformative Learning and Innovation Skills Using Remote Learning for Sustainable Architecture Design. *Sustainability*, *14*(7), 3928. https://doi.org/10.3390/su14073928

Bai, X. J., & Li, J. J. (2021). Applied Research of Knowledge in the Field of Artificial Intelligence in the Intelligent Retrieval of Teaching Resources. *Scientific Programming*, *2021*. https://doi.org/10.1155/2021/9924435

Banaei, M., Ahmadi, A., Gramann, K., & Hatami, J. (2020). Emotional evaluation of architectural interior forms based on personality differences using virtual reality. *Frontiers of Architectural Research*, *9*(1), 138–147. https://doi.org/10.1016/j.foar.2019.07.005

Basarir, L. (2022). Modelling AI in Architectural Education. *Gazi University Journal of Science*, *35*(4), 1260–1278. https://doi.org/10.35378/gujs.967981

Bashabsheh, A. K., Alzoubi, H. H., & Ali, M. Z. (2019). The application of virtual reality technology in architectural pedagogy for building constructions. *Alexandria Engineering Journal*, *58*(2), 713–723. https://doi.org/10.1016/j.aej.2019.06.002

Caliskan, E. B. (2023). Interview with Chat GPT to Define Architectural Design Studio Work: Possibilities, Conflicts and Limits. *Journal of Design Studio*, *5*(1), 57–71. https://doi.org/10.46474/jds.1267485

Cao, Y., Aziz, A. A., & Arshard, W. N. R. M. (2023). University students' perspectives on Artificial Intelligence: A survey of attitudes and awareness among Interior Architecture students. *International Journal of Educational Research and Innovation*, *2023*(20), 1–21. https://doi.org/10.46661/ijeri.8429

Chien, Y. H., & Yao, C. K. (2020). Development of an ai userbot for engineering design education using an intent and flow combined framework. *Applied Sciences (Switzerland)*, *10*(22), 1–14. https://doi.org/10.3390/app10227970

Chun, H. (2021). A Study on the Impact of 3D Printing and Artificial Intelligence on Education and Learning Process. *Scientific Programming*, *2021*, 3–7. https://doi.org/10.1155/2021/2247346

Darwish, M., Kamel, S., & Assem, A. (2023). A Theoretical Model of Using Extended Reality in Architecture Design Education. *Engineering Research Journal - Faculty of Engineering (Shoubra)*, *52*(1), 36–45. https://doi.org/10.21608/erjsh.2022.168677.1099

Dickinson, D. (2020). Christopher Alexander and the Inadequacy of Genius in the Architecture of the Coming Age. *Urban Science*, *4*(2). https://doi.org/10.3390/urbansci4020017

Elsayed, M., Aref, Y., Abdou, S., & Saleh, H. (2020). Using Mobile Augmented Reality Technologies in Architectural Education. *Architecture and Planning Journal (APJ)*, *23*(2). https://doi.org/10.54729/2789-8547.1080

Fareed, M. W., Bou Nassif, A., & Nofal, E. (2024). Exploring the Potentials of Artificial Intelligence Image Generators for Educating the History of Architecture. *Heritage*, *7*(3), 1727–1753. https://doi.org/10.3390/heritage7030081

Hamid Khalili. (2023). *Edinburgh Research Explorer*. *17*(1), 213–232. https://doi.org/10.1017/S0030605311001384

Kumar, A. N. S., & Janardhan, A. J. (2023). The Role of Technology in Shaping the Future of Architectural Education. *INTERANTIONAL JOURNAL OF SCIENTIFIC RESEARCH IN ENGINEERING AND MANAGEMENT*, *07*(12), 1–11. https://doi.org/10.55041/IJSREM27584

Li, W., Xue, Z., Li, J., & Wang, H. (2022). The interior environment design for entrepreneurship education under the virtual reality and artificial intelligence-based learning environment. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.944060

Makaklı, E. S. (2019). STEAM approach in architectural education. *SHS Web of Conferences*, *66*, 01012. https://doi.org/10.1051/shsconf/20196601012

Prasetyo, Y. A., & Habibie, I. (2022). Smart City Architecture Development Framework (SCADEF). *International Journal on Informatics Visualization*, *6*(4), 869–875. https://doi.org/10.30630/joiv.6.4.1537

Raposo Grau, J. F., & Paredes Maldonado, M. (2023). El dibujo de arquitectura. Lenguaje de pensamiento y construcción Pasado, presente y futuro. *VLC Arquitectura. Research Journal*, *10*(2), 225–255. https://doi.org/10.4995/vlc.2023.19679

Royal Institute of British Architect. (2020). *RIBA Publishes Results of Covid-19 Student Survey.*

Sadek, M. (2023). Artificial Intelligence as a pedagogical tool for architectural education: What does the empirical evidence tell us? *MSA Engineering Journal*, *2*(2), 133–148. https://doi.org/10.21608/msaeng.2023.291867

Şahbaz, E. (2020). VR-Based Interactive Learning in Architectural Education: A Case on Safranbolu Historical Bathhouse. *Iconarp International J. of Architecture and Planning*, *8*(1), 342–356.

https://doi.org/10.15320/ICONARP.2020.116

Sampaio, A. Z., Ferreira, M. M., Rosário, D. P., & Martins, O. P. (2010). 3D and VR models in Civil Engineering education: Construction, rehabilitation and maintenance. *Automation in Construction*, *19*(7), 819–828. https://doi.org/10.1016/j.autcon.2010.05.006

Sampaio, A. Z., & Martins, O. P. (2014). The application of virtual reality technology in the construction of bridge: The cantilever and incremental launching methods. *Automation in Construction*, *37*, 58–67. https://doi.org/10.1016/j.autcon.2013.10.015

Sun, C., Hu, W., & Xu, D. (2019). Navigation modes, operation methods, observation scales and background options in UI design for high learning performance in VR-based architectural applications. *Journal of Computational Design and Engineering*, *6*(2), 189–196. https://doi.org/10.1016/j.jcde.2018.05.006

Tong, H., Türel, A., Şenkal, H., Ergun, S. F. Y., Güzelci, O. Z., & Alaçam, S. (2023). Can AI Function as a New Mode of Sketching: A Teaching Experiment with Freshman. *International Journal of Emerging Technologies in Learning*, *18*(18), 234–248. https://doi.org/10.3991/ijet.v18i18.42603

Ummihusna, A., & Zairul, M. (2022a). Exploring immersive learning technology as learning tools in experiential learning for architecture design education. *Open House International*, *47*(4), 605–619. https://doi.org/10.1108/OHI-01-2022-0020

Ummihusna, A., & Zairul, M. (2022b). Investigating immersive learning technology intervention in architecture education: a systematic literature review. *Journal of Applied Research in Higher Education*, *14*(1), 264–281. https://doi.org/10.1108/JARHE-08-2020-0279

Wang, X., Liu, A., & Kara, S. (2022). Machine learning for engineering design toward smart customization: A systematic review. *Journal of Manufacturing Systems*, *65*(October), 391–405. https://doi.org/10.1016/j.jmsy.2022.10.001

Weber, F., Schrumpf, J., Dettmer, N., & Thelen, T. (2022). History, Architecture, and Future of a Digital Data-Driven Study Assistant. *International Journal of Emerging Technologies in Learning*, *17*(22), 246–254. https://doi.org/10.3991/ijet.v17i22.31887

Yang, P., & Liu, X. (2022). Evaluation of Comprehensive Services of an Online Learning Platform Based on Artificial Intelligence. *International Journal of Emerging Technologies in Learning*, *17*(13), 130–144. https://doi.org/10.3991/ijet.v17i13.32797

Zairul, M. (2021a). A thematic Review on Industrialised Building System (IBS) Publications from 2015-2019: Analysis of Patterns and Trends for Future Studies of IBS in Malaysia. *Pertanika Journal of Social Sciences and Humanities*, *29*(1), 635–652. https://doi.org/10.47836/pjssh.29.1.35

Zairul, M. (2021b). Opening the Pandora Box of Issues in the Industrialized Building System in Malaysia : A Thematic Review. *Journal of Applied Science and Engineering*, *25*, 297–310. https://doi.org/10.6180/jase.202204_25(2).0006 1.

Zairul, M. (2023). *Thematic Review template* (003009261–M).

Zairul, M., Azli, M., & Azlan, A. (2023). Defying tradition or maintaining the status quo? Moving towards a new hybrid architecture studio education to support blended learning post-COVID-19. *Archnet-IJAR: International Journal of Architectural Research*. https://doi.org/10.1108/ARCH-11-2022-0251

Zairul, M., & Mohd Zairul. (2020). A THEMATIC REVIEW ON STUDENT-CENTRED LEARNING IN THE STUDIO EDUCATION. *Journal of Critical Reviews*, *7*(02), 504–511. https://doi.org/10.31838/jcr.07.02.95

Zakariya, A. F., Susanti, W. D., & Paryoko, V. G. P. J. (2023). Innovative Integration: Exploring AI Art Platforms in Architectural Education for Mosque Facade Design. *Indonesian Journal of Education and Social Studies*, *2*(1), 47–56. https://doi.org/10.33650/ijess.v2i1.7214