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Essential Components of Framework for Virtual Pedagogy in Architecture Education

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Abstract

The COVID-19 pandemic has significantly disrupted traditional educational practices, forcing institutions to transition to remote or online modalities. This is particularly challenging for architecture education, which has historically relied on the design studio, a highly collaborative and hands-on learning environment. The sudden shift to virtual learning has highlighted the constraints and potential of digital platforms in supporting architectural pedagogy. However, the results seem to be quite unsatisfactory from both teachers & student community on the usage of virtual learning platforms for teaching and learning purposes due to the non-availability of dedicated tools or platforms for delivering architecture education. This study aims to identify the essential components of the framework for virtual pedagogy in architecture education. The research methodology employed in this study involves a systematic literature review of relevant academic sources to identify the key components of a virtual pedagogy framework for architecture education. While these studies provide valuable insights, there remains a need to synthesize the key findings into a cohesive framework to guide the development of virtual pedagogy in architecture education.

1.0 INTRODUCTION

The rapid advancement of digital technologies has been transforming the educational landscape for over a decade, but the onset of the COVID-19 pandemic accelerated this shift in unprecedented ways. Educational institutions across the globe were forced to transition from traditional, in-person learning environments to remote or virtual modalities (Lockee, 2021). This abrupt change has significantly impacted architecture education, a discipline that relies heavily on hands-on learning, interactive environment and collaboration (Abu Alatta et al., 2023). This unique environment of the design studio, which forms the core of architectural pedagogy, is not only a physical space where students develop their design skills but also a social and collaborative environment where they engage with peers, instructors, and the iterative nature of the design process (Grover & Wright, 2023). Transposing this dynamic setting into a virtual format has posed considerable challenges for both students and educators (Fleischmann, 2020). Architecture education's reliance on physical spaces for collaborative design discussions, model making, and immediate feedback means that traditional educational technologies, which may suffice in other disciplines, often fall short in meeting its pedagogical needs (Srirangam & Ng, 2022). The sudden shift to online learning during the pandemic has exposed significant gaps in the availability of suitable digital tools tailored to the specific requirements of architecture education. While various online platforms have been adopted to facilitate learning, as they lack the dedicated features necessary to replicate the immersive and interactive nature of the design studio. Consequently, both students and educators have reported dissatisfaction with the virtual learning experience, citing difficulties in replicating the depth of critique, collaboration, and tactile learning that are integral to architectural training (Hettithanthri & Hansen, 2022). The dissatisfaction stems largely from the limitations of existing virtual learning platforms in addressing the complexity of architectural education. Most virtual platforms were not designed with architecture in mind, and the general-purpose nature of these tools creates barriers to fully engaging students in the design process (Asfour & Alkharoubi, 2023). Furthermore, the virtual learning environment has highlighted a critical need for effective pedagogical frameworks that can bridge the gap between traditional architecture education and digital modalities. Without a well-structured and targeted approach to virtual pedagogy, architecture education risks losing the key experiential and collaborative elements that are fundamental to students' development as architects (Iranmanesh & Onur, 2021b). The need to develop a comprehensive framework for virtual pedagogy in architecture education is therefore pressing. Such a framework would not only address the current gaps but also serve as a roadmap for integrating digital tools and methodologies in a manner that enhances, rather than diminishes, the educational experience (Marcarini, 2021).

This study aims to identify the essential components of a virtual pedagogy framework specifically designed for architecture education. Given the discipline's reliance on hands-on learning, iterative design, and studio-based collaboration, transitioning to digital platforms presents unique challenges. This research seeks to define a structured approach that preserves these fundamental aspects while enhancing engagement, collaboration, and experiential learning in virtual environments. Through a comprehensive review of academic literature and existing virtual education models, this study aims to establish guiding principles for effective digital pedagogy. As online education continues to evolve, architecture requires a framework that aligns with its discipline-specific needs rather than relying on generic digital learning models. Without such a structure, virtual learning risks diminishing the experiential and collaborative qualities integral to architectural pedagogy. By identifying and synthesising these essential components, this research not only contributes to the broader discourse on digital education but also provides a foundation for integrating virtual pedagogy as a long-term, complementary approach in architectural curricula. In an era where digital tools are increasingly shaping architectural practice, a well-structured virtual pedagogy framework is crucial for preparing future architects to navigate and contribute to this evolving landscape.

1.1 Virtual Pedagogy in Architecture Education

Virtual pedagogy has transformed higher education, especially in disciplines traditionally reliant on physical interaction and practice-based learning, such as architecture. As architecture education integrates both theoretical knowledge and practical skills, transitioning this pedagogy to a virtual platform presents unique challenges. A robust framework is required to effectively facilitate virtual pedagogy in architecture education, addressing the unique nature of architectural teaching, design thinking, studio culture, and the use of digital tools (Fadjar Maharika et al., 2020). This literature review examines the essential components of a framework for effective virtual pedagogy in architecture education, drawing on various scholarly works that highlight key

areas such as curriculum development, studio environments, technological integration, and student engagement.

1.2 Current Trends in Virtual Pedagogy

Over the past two decades, virtual pedagogy has witnessed significant advancements, driven by technological innovation and the increasing global reliance on digital learning environments (Loures Brandão et al., 2018). Technologies such as virtual reality (VR), augmented reality (AR), and 3D modelling software have become prominent in enhancing educational experiences (Tan et al., 2022). In architecture education, tools like Autodesk Revit, Rhino, SketchUp, and immersive VR environments allow students to design, visualise, and interact with architectural models in ways that transcend traditional media. VR-based tools such as Enscape and Unity provide immersive spatial experiences, enabling students to virtually "walk through" their designs, an aspect critical to architectural understanding (Asfour & Alkharoubi, 2023). Collaborative tools, including platforms like Miro, Google Jam board, and Microsoft Teams, support real-time interaction and teamwork, mimicking the collaborative nature of design studios. Cloud-based solutions like BIM 360 and shared 3D repositories further enable seamless file sharing and co-creation (Collis & Wende, 2002). Additionally, Learning Management Systems (LMS) like Moodle, Blackboard, and Canvas are increasingly being tailored to integrate discipline-specific features, allowing for synchronised feedback and structured critiques. Beyond this, the integration of AI-driven learning platforms and adaptive technologies has shown promise in providing personalised feedback and enhancing student engagement (Sofianos et al., 2024). These trends indicate a shift from merely digitising education to creating dynamic, interactive, and student-centred virtual learning environments (Anderson & Dron, 2011).

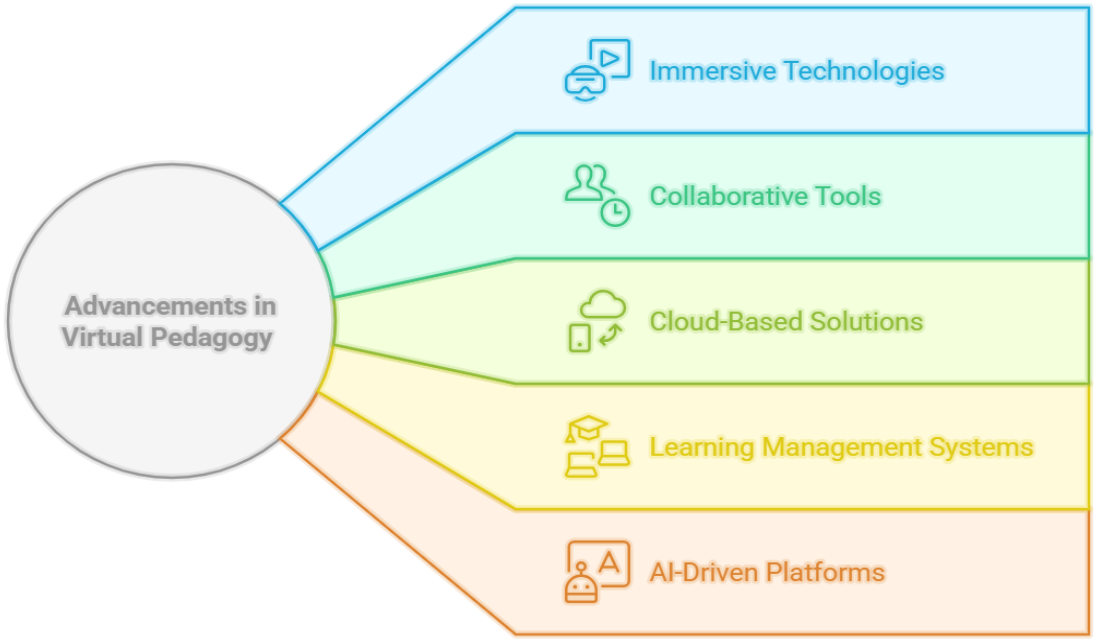

Figure 1. Advancements in Virtual Pedagogy.

1.3 Theoretical Underpinnings of Virtual Pedagogy

Several educational theories shape the design and implementation of virtual pedagogy frameworks, especially in architecture, a discipline that depends heavily on experiential, iterative, and collaborative learning. Constructivism underscores that learners build knowledge through active engagement and interaction, which in architectural pedagogy is reflected in the design studio process of conceptualising, testing, and refining ideas; here, virtual platforms such as 3D design tools and VR environments support real-time experimentation and feedback (Schon, 1987). Kolb's experiential learning cycle further reinforces this by highlighting the interconnected stages of experience, reflection, conceptualisation, and experimentation, a cycle mirrored in architecture's hands-on projects and real-world simulations, which virtual platforms like Unity and SketchUp successfully replicate by converting abstract ideas into tangible outcomes (Kolb, 2014;

Guo et al., 2024) . Complementing this, collaborative learning theory recognises the social and collective nature of design education, with digital tools such as Zoom, Miro, and Slack enabling peer-to-peer critique, idea exchange, and group problem-solving, thereby sustaining the dynamics of traditional studio culture in online environments (Milovanovic et al., 2017). Finally, Lave and Wenger's situated learning theory, which views learning as embedded within social and cultural contexts, finds resonance in architecture's studio-based pedagogy, where digital communities and virtual studios foster a sense of belonging, shared practice, and professional enculturation, thus ensuring that virtual pedagogy not only transmits knowledge but also sustains the cultural ethos of architectural education (Lave & Wenger, 1991; Harry & Kumar, 2022).

Figure 2. Learning Theories for Virtual Pedagogy.

1.4 Challenges in Architecture Education

Despite notable advancements in virtual pedagogy, architecture education continues to face distinct challenges due to its deep reliance on spatial, tactile, and iterative modes of learning. The design studio, which forms the heart of architectural education, is traditionally an interactive, hands-on environment where students benefit from immediate feedback, peer-to-peer exchange, and iterative design processes. Replicating this pedagogy in virtual spaces remains a persistent challenge, as conventional online tools often fall short in reproducing the collaborative dynamics and embodied spatial understanding cultivated in physical studios (Mariotti & Niblock, 2023). Visualization technologies, though increasingly sophisticated, also struggle to replace the tactile dimension of physical model-making. The absence of haptic feedback in digital environments diminishes learners' ability to fully grasp materiality, scale, and spatial relationships, with virtual reality offering immersive spatial experiences but failing to replicate the nuanced physical interactions with models and materials (Maghool et al., 2018; Guo et al., 2024). Another critical issue arises in balancing synchronous and asynchronous learning. While synchronous platforms allow for real-time critique and interaction, they rarely achieve the richness of in-person discussions, whereas asynchronous methods though flexible often risk disengagement and fragmented learning experiences (Estrina et al., 2021a). Moreover, the effectiveness of either mode is closely tied to the availability of trained faculty who can adapt to digital teaching environments, an aspect that remains underdeveloped in many institutions and requires greater professional development initiatives. Finally, accessibility and equity remain pressing concerns. The high cost of VR devices, high-performance computing systems, and licensed software creates barriers for students in resource-constrained contexts, limiting inclusive participation and raising questions about equitable access to virtual architectural education (Sepasgozar, 2020). Addressing these gaps demands not only technological innovation but also the evolution of pedagogical strategies and institutional frameworks that prioritize inclusivity, adaptability, and context-sensitive solutions for future architectural education.

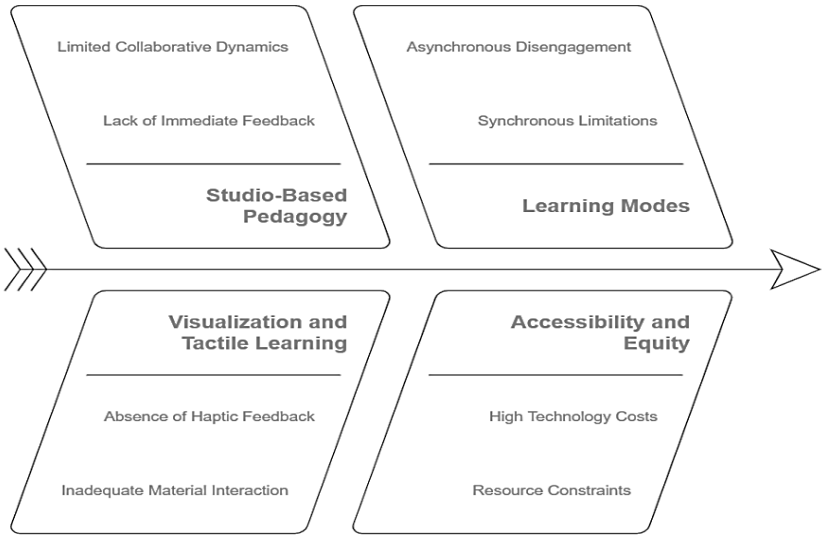

Figure 3. Challenges in Virtual Pedagogy.

1.5 Successful Models and Gaps in Existing Frameworks

Certain disciplines have successfully integrated virtual pedagogy into their curricula, offering valuable insights that can inform architecture education. For instance, engineering and healthcare have developed robust virtual education frameworks that demonstrate the possibilities of digital learning. In engineering, virtual labs and simulations allow students to engage with complex systems in a controlled environment, providing opportunities for experimentation and skill development without the risks associated with physical settings (Milovanovic et al., 2017). Similarly, healthcare education employs VR and AR to simulate medical procedures, thereby enabling experiential learning in virtual spaces and cultivating professional competencies in safe yet realistic contexts (Estrina et al., 2021a). These examples underscore the potential of digital tools to replicate hands-on experiences and foster discipline-specific training. However, in the case of architecture, the adoption of virtual pedagogy has remained fragmented and inconsistent, with individual institutions independently experimenting with platforms such as Enscape, Lumion, and Revit. While these tools offer valuable opportunities for immersive visualization, they often operate in isolation and fail to integrate into a cohesive pedagogical framework that mirrors the collaborative and iterative culture of design studios. This fragmented approach highlights a significant gap: the absence of a unified framework tailored specifically to the unique needs of architectural pedagogy. Existing digital platforms remain largely general-purpose, inadequately addressing the nuanced requirements of studio-based learning. Notable deficiencies include the lack of tools that provide real-time tactile feedback, the absence of integrated collaborative environments that can foster peer-to-peer and faculty-student engagement, and limited methods for replicating iterative design critiques in a meaningful virtual format (Mariotti & Niblock, 2023). To move forward, architecture education must draw on successful models from allied disciplines and adapt them to its studio-centered traditions, integrating immersive technologies with collaborative digital platforms and developing structured frameworks that balance visualization, interactivity, and critical feedback. Such an approach will not only bridge the existing gaps but also establish a sustainable roadmap for the long-term integration of virtual pedagogy in architectural curricula.

2.0 METHODOLOGY

This study adopts a sequential mixed-methods design comprising three interlinked phases: literature review, questionnaire-based validation, and triangulated corroboration of data. The first phase involved a systematic review of 140 peer-reviewed studies (2015–2025) sourced from Google Scholar, Scopus, Web of Science, JSTOR, and IEEE Xplore, using targeted keywords and Boolean operators, with inclusion criteria emphasizing architecture education, digital learning, and pedagogical frameworks; interpretive synthesis of recurring themes enabled the identification of preliminary framework components. In the second phase, a structured questionnaire with 62 item statements across ten thematic sections was developed, incorporating

demographic/contextual data and Likert-scale ratings to assess component relevance; it was digitally circulated across Indian architecture schools, yielding 815 valid responses (486 students, 329 faculty), which were analysed using descriptive statistics (mean, median, mode, standard deviation, variance), with components validated at mean ≥4.0. The third phase employed triangulated corroboration to align literature-derived insights with empirical results through comparative interpretation of statistical outputs and thematic constructs, confirming convergence across most components while highlighting areas needing institutional or pedagogical strengthening. This rigorous, multi-layered methodology ensures theoretical integrity, empirical reliability, and contextual applicability in proposing a framework for virtual pedagogy in architecture education.

2.1 Analysis of Systematic Literature Review

The effectiveness of virtual pedagogy in architecture education demands more than a broad discussion of digital teaching strategies. Owing to the discipline's deep-rooted emphasis on studio-centric instruction, spatial visualization, and experiential collaboration, it is imperative to investigate the nuanced implications of transitioning these pedagogical dimensions into virtual formats. Rather than relying on generalized evaluations, a detailed, component-specific inquiry becomes crucial to uncover the enablers and impediments embedded within this transformation. This analytical approach facilitates a deeper understanding of the pedagogical and structural shifts necessary for effective and enduring digital integration. To meet this objective, the present research conducted an extensive analysis of more than 140 scholarly publications, aiming to extract prevailing patterns, methodologies, and issues associated with online architecture education. Employing a rigorous iterative process involving thematic analysis, categorization, and theoretical mapping, the study identified ten core components central to virtual pedagogy. These components were not pre-defined; instead, they consistently surfaced across multiple sources, indicating their critical relevance to the continuity and quality of architectural learning in digital environments.

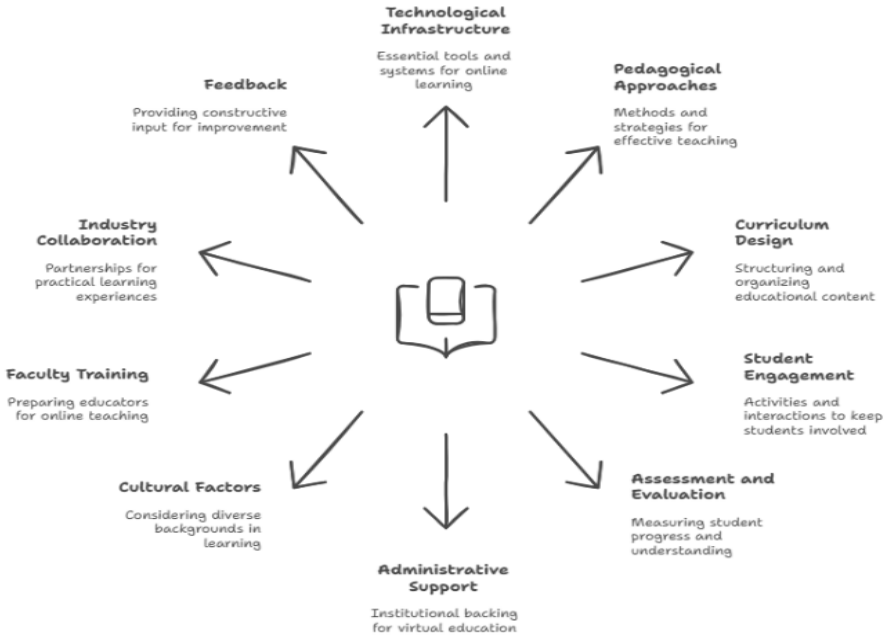

Figure 4. Components of the framework.

Each component addresses a particular dimension of the virtual education landscape ranging from digital infrastructure and instructional strategies to learner engagement, institutional mechanisms, and long-term adaptability. Collectively, these elements constitute an integrated framework that encapsulates the multifaceted challenges and opportunities inherent in transitioning architectural pedagogy to virtual platforms. This framework thus provides a substantive basis for evaluating and advancing the design and delivery of virtual pedagogy within the architectural education domain.

The arrangement of the identified components adheres to a purposeful hierarchy shaped by two key considerations: the extent of their pedagogical significance as evidenced in academic discourse, and the frequency with which they recur throughout the reviewed body of literature. Components deemed foundational

such as technological infrastructure, instructional models, and curriculum modification are placed at the forefront of the framework due to their centrality and consistent emphasis across scholarly discussions. In contrast, components that, although relevant, were less prominently featured or appeared with lower frequency such as adaptive learning systems and advanced interactivity design are situated later in the sequence. This structured ordering facilitates a stratified comprehension of the virtual pedagogy domain, foregrounding essential educational priorities while also integrating emergent, context-specific elements.

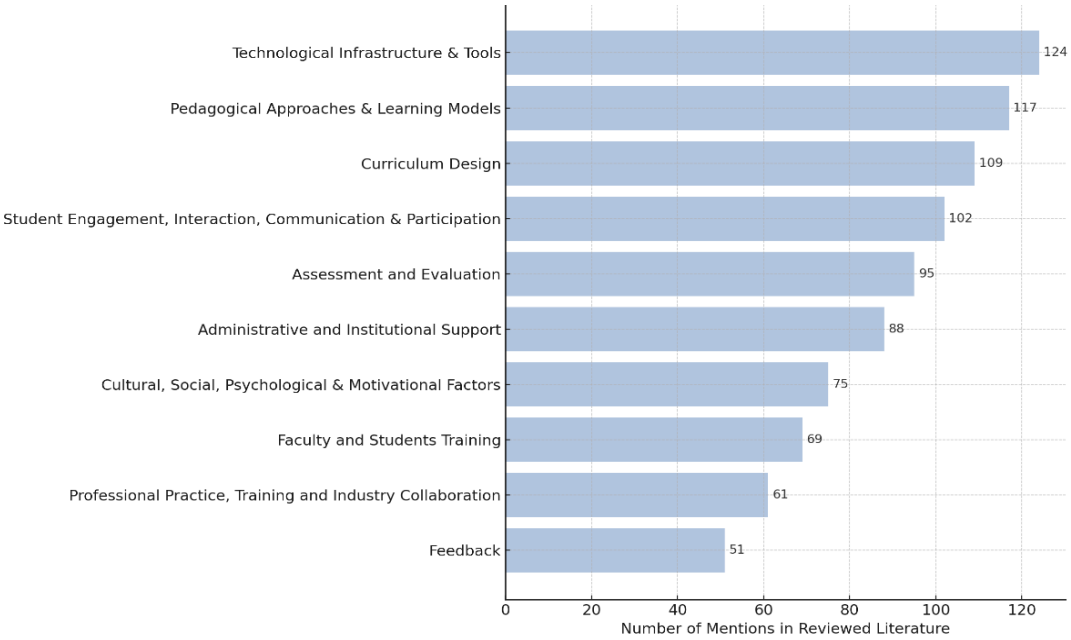

Figure 5. Hierarchy Identified Components of Framework

The framework for virtual pedagogy in architecture education comprises ten interdependent domains that, taken together, span the pedagogical, technological, institutional, and socio-cultural conditions necessary for effective digital design learning. These domains were derived through rigorous thematic analysis of more than 140 scholarly sources and refined iteratively to collapse overlaps and sharpen conceptual boundaries, resulting in a contextually grounded structure responsive to the particular demands of architectural pedagogy in online and hybrid environments. At its base lies Technological Infrastructure & Tools including hardware access, bandwidth and connectivity, platform reliability, and discipline-specific software without which virtual delivery lacks operational viability. Equally essential are Pedagogical Approaches & Learning Models that sustain constructivist, reflective, and student-centred teaching traditions as instruction moves beyond the physical studio. Curriculum Design for Digital Delivery must retain the spatial, experiential, and project-driven ethos of architecture while incorporating flexibility, adaptability, and accreditation compliance across modes. Anchoring the human dimension of the framework is Student Engagement, Interaction, Communication & Participation, which seeks to recreate (and strategically extend) the collaborative, dialogic culture of the design studio in mediated settings. This is reinforced by Assessment & Evaluation Practices calibrated for iterative design learning emphasising formative feedback, process transparency, and multi-stage critique rather than purely summative measurement**.** The sustainability of these pedagogical transformations is contingent upon strong administrative and institutional support, encompassing policy reforms, strategic investment in digital infrastructure, and the empowerment of faculty. The framework also emphasizes the critical need to address cultural, social, psychological, and motivational dimensions to foster inclusivity, ensure accessibility, and promote emotional well-being within virtual learning environments. Capacity-building initiatives for both educators and students are identified as key enablers, helping to bridge digital literacy gaps and cultivate pedagogical adaptability. Furthermore, the integration of professional practice, experiential training, and industry collaboration ensures that architecture education retains its relevance by maintaining alignment with real-world workflows, virtual site simulations, and active practitioner involvement. Finally, the feedback component operates as a dynamic, formative loop integral to sustaining the reflective, iterative nature of studio-based learning. Collectively, these ten components constitute a comprehensive, adaptable, and scalable framework that is theoretically robust, operationally practical, and pedagogically attuned to the evolving demands of architecture education in the digital age.

i. **Technological Infrastructure & Tools:** A robust technological infrastructure forms the backbone of virtual pedagogy in architecture. Essential tools such as Revit, Rhino, SketchUp, and Enscape support advanced design visualisation and modelling (Guo et al., 2024). Collaborative platforms like BIM 360 and Miro enable shared workflows, while VR environments and high-performance computing hardware foster immersive spatial experiences (Sepasgozar, 2020; Tan et al., 2022). The accessibility, integration, and stability of these tools critically influence the pedagogical effectiveness and inclusivity of virtual design studios.

ii. **Pedagogical Approaches & Learning Models:** Adapting studio-based learning into virtual formats requires innovative pedagogical strategies rooted in constructivism, experiential learning, and collaborative models (Schon, 1987; Kolb, 2014; Milovanovic et al., 2017). Blended learning, flipped classrooms, and project-based studio tasks have shown effectiveness in maintaining engagement and fostering critical thinking (Fadjar Maharika et al., 2020; Harry & Kumar, 2022). These approaches ensure the continuity of the reflective and iterative learning process essential in design education (Grover & Wright, 2023).

iii. **Curriculum Design:** Virtual pedagogy necessitates curriculum reconfiguration to enhance modularity, thematic flexibility, and digital integration. Digital restructuring of studio curricula and the inclusion of interdisciplinary themes such as sustainability, AI, and digital fabrication have been identified as necessary for relevance and adaptability (Iranmanesh & Onur, 2021b; Srirangam & Ng, 2022). Accreditation alignment through learning outcomes and skill-based segmentation is also critical (Fadjar Maharika et al., 2020).

iv. **Student Engagement, Interaction, Communication & Participation:** Sustaining engagement in digital platforms requires fostering peer interaction, design dialogue, and studio culture. Virtual critiques, design pin-ups, breakout sessions, and online design charrettes have shown promise in replicating in-person dynamics (Estrina et al., 2021b; Hettithanthri & Hansen, 2021). Communication tools such as Teams, Slack, and Zoom facilitate multi-channel interaction, while gamification strategies enhance motivation (Loures Brandão et al., 2018).

v. **Assessment and Evaluation:** Assessment in virtual settings must go beyond traditional grading models. Digital portfolios, peer critiques, and rubric-based evaluation promote transparency and student reflection (Asfour & Alkharoubi, 2023). Virtual juries and live design presentations are effective for maintaining studio rigour and offering formative feedback aligned with architectural thinking (Hettithanthri & Hansen, 2021).

vi. **Administrative and Institutional Support:** Institutional backing plays a pivotal role in enabling the transition to virtual pedagogy. Policies around digital access, IT support, academic regulations, and learning management systems (LMS) influence the consistency and scalability of virtual delivery (Lockee, 2021). Institutional strategies must address licensing, access to technology, and faculty incentives to ensure long-term adoption (Marcarini, 2021).

vii. **Cultural, Social, Psychological & Motivational Factors:** Design education is profoundly influenced by student well-being, cultural identity, and motivational context. Online settings may lead to feelings of disconnection and reduced creative energy (Grover & Wright, 2023). Integrating inclusive practices, empathy-driven mentoring, and socio-cultural relevance in studio projects can help mitigate these effects (Mariotti & Niblock, 2023).

viii. **Faculty and Students Training:** Training programs are essential for digital competency. Faculty need support in virtual studio facilitation, digital tool mastery, and online pedagogy (Fadjar Maharika et al., 2020). Students equally benefit from orientation in collaborative software, data ethics, and remote critique protocols (Iranmanesh & Onur, 2021b). Institutions must implement structured workshops and peer support systems to ensure capacity-building.

ix. **Professional Practice, Training and Industry Collaboration:** Virtual platforms allow innovative engagement with industry professionals. Online internships, virtual guest lectures, and digital design competitions simulate real-world exposure and foster skill alignment with practice (Tan et al., 2022). These interactions help embed employability and professionalism in virtual studio culture.

x. **Feedback:** Timely, multi-modal feedback enhances the effectiveness of virtual pedagogy. Annotated screenshots, recorded critiques, and voice comments simulate the traditional pin-up environment while offering personalisation (Sofianos et al., 2024). Bidirectional feedback mechanisms, allowing students to evaluate courses and teaching effectiveness, strengthen responsiveness and instructional quality (Estrina et al., 2021b).

Table 1. Virtual Pedagogy Framework Components.

Components	Rationale	Scope & operational boundaries,	Source
Technological Infrastructure & Tools	This component serves as the foundational backbone of any virtual pedagogy framework. In the absence of reliable technological infrastructure including access to appropriate hardware, stable internet connectivity, discipline-specific software, and collaborative digital platforms the effective delivery of design-centric architectural education becomes unviable.	This component comprises the full spectrum of physical and digital infrastructure necessary to operationalize virtual pedagogy. It includes access to computing devices, adequate internet bandwidth, licensed discipline-specific software such as AutoCAD, Revit, and Rhino, as well as cloud storage solutions, learning management systems (LMS), and ongoing IT support. Additionally, it encompasses critical operational features such as system scalability, data security protocols, and cross-platform interoperability each essential to sustaining the technical demands of architecture-focused digital education.	(Guo et al., 2024); (Sepasgozar, 2020); (Tan et al., 2022) (Jena, 2020) (Coman et al., 2020) (Varma & Jafri, 2021)
Pedagogical Approaches & Learning Models	The shift to virtual pedagogy necessitates a fundamental re-evaluation of traditional instructional methods. Pedagogical strategies rooted in constructivist, learner-centred, and design-based principles must be thoughtfully reconfigured to align with the affordances and constraints of digital learning environments.	This component incorporates a range of pedagogical strategies tailored to the specificities of architecture education, including project-based learning, flipped classroom models, blended studio formats, collaborative design processes, synchronous critique sessions, and the integration of digital storytelling as a medium for design communication and reflection.	(Fadjar Maharika et al., 2020; Kolb, 2014; Schon, 1987) (Iranmanesh & Onur, 2021b)
Curriculum Design	The curriculum serves as the structural framework through which educational objectives are articulated and achieved. Within the context of virtual pedagogy, the architecture curriculum must be thoughtfully restructured to integrate digital tools and workflows, while preserving the discipline's inherent emphasis on spatial reasoning, contextual sensitivity, and experiential learning.	This component includes comprehensive course mapping, incorporation of digital site analysis, adaptive sequencing of content delivery, and the redesign of studio modules to suit virtual and hybrid formats. It also involves structuring blended studio-workshop environments and ensuring curricular alignment with national and international accreditation standards relevant to architecture education.	(Iranmanesh & Onur, 2021b); (Srirangam & Ng, 2022) (Khalil et al., 2021) (Ceylan et al., 2021)

Student Engagement, Interaction, Communication, & Participation	Student engagement and interactive participation lie at the heart of architectural studio culture. The transition to virtual platforms, however, poses the risk of diminished learner involvement unless intentional pedagogical strategies are implemented to foster meaningful dialogue, collaborative exchanges, and creative exploration within the digital environment.	This component encompasses various mechanisms for fostering engagement, including peer-to-peer communication, faculty-student interaction, virtual pin-up reviews, breakout studio sessions, and the use of collaborative digital platforms such as Miro and Padlet. It also includes strategies for tracking student participation and implementing both synchronous and asynchronous modes of interaction to sustain an active and inclusive learning environment.	(Estrina et al., 2021a); (Hettithanthri & Hansen, 2021); (Loures Brandão et al., 2018) (Grover & Wright, 2023)
Assessment and Evaluation	Assessment in architectural education must account for both the final design outcomes and the underlying creative processes. In virtual learning environments, this necessitates the development of innovative and dependable evaluation methods that align with the iterative, process-oriented, and qualitative nature of design pedagogy.	This component incorporates a range of assessment strategies suited to virtual design education, including digital portfolios, formative evaluation tools, peer review mechanisms, process-oriented assessment rubrics, video-based critique formats, and the emerging use of AI-driven analytics to support reflective and data-informed evaluation practices.	(Asfour & Alkharoubi, 2023); (Hettithanthri & Hansen, 2021) (Ummihusna & Zairul, 2022)
Administrative and Institutional Support	The long-term viability of virtual pedagogy relies heavily on proactive administrative facilitation and sustained institutional support. In the absence of such backing, even well-conceived pedagogical models and technological systems are likely to encounter significant implementation challenges.	This component encompasses a broad range of institutional responsibilities, including policy formulation, strategic scheduling, faculty workload redistribution, provision of IT support services, allocation of funding for digital infrastructure, implementation of institutional training programs, and adherence to academic regulatory and accreditation frameworks.	(Lockee, 2021); (Marcarini, 2021) (Alnusairat et al., 2021)
Cultural, Social and Psychological & Motivational Factors	Virtual learning environments have the potential to intensify challenges related to exclusion, social isolation, and student disengagement. This component addresses the need to maintain a human-centered pedagogical approach that is responsive to the diverse socio-cultural, psychological, and	This component encompasses key dimensions such as language and cultural sensitivity, inclusive and accessible content design, attention to learners' psychological well-being, support for learner autonomy, and the implementation of socio-emotional engagement strategies. It also includes motivation-enhancing interventions aimed at fostering a supportive and equitable virtual learning environment.	(Grover & Wright, 2023); (Mariotti & Niblock, 2023) (Megahed & Hassan, 2022)

	contextual realities of learners.		
Faculty and Students Training	The effectiveness of virtual pedagogy is fundamentally dependent on the digital competence and pedagogical preparedness of both educators and learners. Targeted training initiatives play a critical role in ensuring that faculty and students are adequately equipped to engage with digital tools, platforms, and instructional methodologies in a confident and effective manner.	This component includes structured onboarding programs, ongoing professional development initiatives, practical training in design software and learning management systems (LMS), pedagogical workshops focused on virtual instruction, guidance on digital ethics, and systematic evaluation of digital competencies for both faculty and students.	(Fadjar Maharika et al., 2020); (Iranmanesh & Onur, 2021a) (Coman et al., 2020)
Professional Practice, Training and Industry Collaboration	Maintaining professional relevance is essential for architecture education, even within virtual learning environments. This component safeguards the continuity of practice-based learning by facilitating student exposure to real-world design workflows, industry standards, and professional practices.	This component encompasses a range of initiatives designed to bridge academic learning with professional practice, including online internships, virtual studio collaborations with architectural firms, guest lectures by industry professionals, digital site explorations, simulated office environments, and the integration of industry-standard tools and workflows into the teaching-learning process.	(Tan et al., 2022); (Milovanovic et al., 2017) (Garg et al., 2022)
Feedback	Feedback plays a pivotal role in supporting iterative design development and fostering student growth. Within virtual learning environments, the establishment of structured, timely, and dialogic feedback mechanisms is essential to replicating the formative critique culture that characterizes traditional architectural design studios.	This component comprises structured critique sessions, annotated digital submissions, the use of real-time design feedback tools, asynchronous video-based commentary, peer-to-peer feedback loops, and systems for tracking longitudinal feedback to monitor student progress over time.	(Sofianos et al., 2024); (Estrina et al., 2021a) (Balbo, 2024)

2.2 Analysis of Questionnaire

The statistical validation of the ten core components proposed for a virtual pedagogy framework in undergraduate architecture education was performed through a structured quantitative analysis based on 815 survey responses. Table 2 presents a concise yet comprehensive profile of each component by reporting the number of survey items, the range of mean and standard deviation scores, as well as the overall mean and standard deviation. The findings confirm that all ten components achieved an overall mean score of 4.0 or above on a 5-point Likert scale, establishing strong empirical support for their inclusion in the final pedagogical framework.

Table 2 .Descriptive Summary of Core Framework Components Based on Questionnaire Responses

S. No.	Component	Items Count	Mean Range	Overall Mean	Std. Dev. Range	Overall Std. Dev.
1	Technological Infrastructure & Tools	10	4.02 – 4.56	4.23	0.58 – 0.72	0.63
2	Pedagogical Approaches & Learning Models	8	4.00 – 4.48	4.15	0.62 – 0.81	0.69
3	Curriculum Design	7	3.98 – 4.40	4.22	0.62 – 0.80	0.68
4	Student Engagement, Interaction, Communication & Participation	5	3.98 – 4.45	4.20	0.60 – 0.71	0.64
5	Assessment & Evaluation	6	4.04 – 4.38	4.21	0.59 – 0.75	0.69
6	Administrative and Institutional Support	6	3.99 – 4.47	4.27	0.61 – 0.73	0.66
7	Cultural, Social, Psychological & Motivational Factors	6	3.93 – 4.49	4.24	0.60 – 0.80	0.67
8	Faculty & Students Training	5	4.07 – 4.47	4.26	0.59 – 0.73	0.68
9	Professional Practice, Training and Industry Collaboration	5	3.96 – 4.28	4.13	0.61 – 0.78	0.69
10	Feedback	4	4.04 – 4.20	4.10	0.68 – 0.81	0.73

Among the components, Administrative and Institutional Support (Mean = 4.27), Faculty and Students Training (Mean = 4.26), Cultural, Social, Psychological & Motivational Factors (Mean = 4.24), and Technological Infrastructure & Tools (Mean = 4.23) emerged as the most highly endorsed domains, reflecting a high degree of consensus among participants. These components not only received high mean scores but also maintained relatively low standard deviations (ranging from 0.63 to 0.68), indicating a consistent perception of their relevance across diverse academic institutions and respondent roles. Curriculum Design and Student Engagement, Interaction, Communication & Participation also demonstrated strong support with overall mean scores of 4.22 and 4.20, respectively.

In contrast, components such as Professional Practice, Training & Industry Collaboration and Feedback recorded slightly lower mean values (4.13 and 4.10, respectively) and relatively higher standard deviation ranges (up to 0.81). These patterns suggest that while these domains are still regarded as important, there may be variations in institutional capacities, exposure levels, or participant experiences that influence their perceived impact. Similarly, the component Pedagogical Approaches & Learning Models displayed a wider dispersion of responses (SD up to 0.81), possibly due to differences in faculty training, familiarity with virtual teaching paradigms, or infrastructural readiness to adopt varied pedagogical models.

Overall, the narrow spread in the mean values (ranging from 4.10 to 4.27) and the controlled variation in standard deviation indicate strong internal consistency of the scale and confirm that the questionnaire was well-structured and statistically robust. The analysis provides empirical clarity on the relative strength and stakeholder agreement regarding each component, thereby laying a strong quantitative foundation for the next phase of the research triangulation with literature and expert inputs to finalize and contextualize the framework for virtual pedagogy in architecture education.

2.3 Corroboration of Data

The corroboration of findings in this study is achieved through a convergence of two critical sources: the thematic literature review and the statistical analysis of primary survey data. This dual approach reinforces the

validity and applicability of the proposed framework for virtual pedagogy in architecture education. The components identified through literature such as technological infrastructure, student engagement, faculty training, and assessment strategies were each tested via a structured questionnaire distributed to 815 respondents, including both students and faculty. The statistical validation revealed strong agreement across all ten components, with each registering an overall mean score above 4.0 on a 5-point Likert scale. Components such as Administrative and Institutional Support (Mean = 4.27), Faculty and Students Training (Mean = 4.26), and Technological Infrastructure & Tools (Mean = 4.23) received particularly high ratings, indicating their perceived centrality in effective virtual pedagogy.

This empirical evidence is further supported by the literature, which consistently emphasises the importance of digital readiness, pedagogical adaptability, and structured institutional support in enabling meaningful learning experiences in virtual environments. The component Professional Practice, Training & Industry Collaboration (Mean = 4.13), although validated, showed relatively lower ratings, echoing literature that highlights the challenges of replicating industry exposure in a virtual format as shown in table 3. Thus, the data corroboration confirms that the framework components are not only statistically significant but also contextually grounded in existing scholarly discourse, strengthening the reliability and applicability of the proposed model within architecture education in India.

Table 3. Corroboration of Core Framework Components through Literature and Empirical Evidence.

S. No.	Component	Literature Data	Quantitative Data	Corroboration
1	Technological Infrastructure & Tools	Supported by 124 data sources	Overall Mean: 4.23, Overall Std. Dev.: 0.63	The quantitative results strongly support the literature, indicating a clear consensus on the essential role of technological readiness. High mean and mode values, combined with a low standard deviation, confirm widespread agreement.
2	Pedagogical Approaches & Learning Models	Supported by 117 data sources	Overall Mean: 4.15, Overall Std. Dev.: 0.69	The data supports the literature by showing strong respondent agreement on the significance of pedagogical diversity. Moderate dispersion reflects varying levels of experience but a common understanding of its importance.
3	Curriculum Design	Supported by 109 data sources	Overall Mean: 4.22, Overall Std. Dev.: 0.68	Quantitative findings reinforce the need for curriculum reformation in virtual pedagogy. The close proximity of mean, median, and mode reflects strong alignment across respondents.
4	Student Engagement, Interaction, Communication & Participation	Supported by 102 data sources	Overall Mean: 4.20, Overall Std. Dev.: 0.64	The data affirms literature advocating active student involvement. High central tendency measures and low variability indicate uniform endorsement of this component.
5	Assessment & Evaluation	Supported by 95 data sources	Overall Mean: 4.21, Overall Std. Dev.: 0.69	The quantitative analysis substantiates the literature's emphasis on innovative evaluation in virtual settings. Consistent responses validate these components' inclusion.
6	Administrative and Institutional Support	Supported by 88 data sources	Overall Mean: 4.27, Overall Std. Dev.: 0.66	The highest overall mean score across all components highlights the central role of institutional backing in virtual pedagogy. Quantitative responses suggest a strong agreement among stakeholders on the importance of structured support,

				administrative clarity, and digital governance in facilitating effective online learning ecosystems. These findings substantiate literature emphasizing institutional preparedness as foundational for successful virtual transitions.
7	Cultural, Social, Psychological & Motivational Factors	Supported by 75 data sources	Overall Mean: 4.24, Overall Std. Dev.: 0.67	This component reflects growing awareness of non-academic factors shaping learner success in virtual settings. The strong statistical support, with a mean of 4.24 and low variability, affirms the literature's concern for inclusivity, learner well-being, and cultural context. These findings suggest that social and emotional dimensions are not peripheral, but integral to the effectiveness of digital architectural education.
8	Faculty & Students Training	Supported by 69 data sources	Overall Mean: 4.26, Overall Std. Dev.: 0.68	Quantitative findings align with numerous scholarly calls for improving digital competence among both learners and educators. The components of the second-highest mean and narrow standard deviation range confirm that training and capacity-building are universally acknowledged as prerequisites for sustaining virtual pedagogy. This widespread agreement reinforces the urgency of institutional investment in structured training programs.
9	Professional Practice, Training and Industry Collaboration	Supported by 61 data sources	Overall Mean: 4.13, Overall Std. Dev.: 0.69	Although this component received the lowest overall mean, it still exceeds the validation threshold. The results reflect a shared concern in the literature regarding the gap between academic learning and industry preparedness in virtual formats. The moderately higher standard deviation indicates variability in implementation across institutions, signaling the need for more structured virtual industry interactions and practice-based exposure.
10	Feedback	Supported by 51 data sources	Overall Mean: 4.10, Overall Std. Dev.: 0.73	This component, though registering the lowest among the ten, remains statistically validated. Literature underscores feedback as essential for reflective learning and academic growth, especially in remote environments. The slightly higher variability suggests inconsistent deployment or understanding of feedback systems across institutions. Nonetheless, the consensus around its importance is evident and warrants more consistent integration in virtual pedagogy frameworks.

3.0 CONCLUSIONS

This study has developed and validated a comprehensive framework comprising ten core components essential for implementing virtual pedagogy in undergraduate architecture education. The research employed a sequential mixed-methods approach beginning with an in-depth literature review, followed by quantitative validation through a large-scale questionnaire, and culminating in a triangulated corroboration of conceptual and empirical findings. The results demonstrate a strong level of consensus among students and faculty members regarding the relevance, necessity, and interdependence of the identified components. Particularly high validation scores were observed for aspects such as technological infrastructure, institutional support, faculty and student training, and pedagogical adaptability indicating their criticality in designing effective digital learning environments for architecture. The findings reinforce the argument that virtual pedagogy in architecture cannot rely solely on digital tools or platforms. Instead, it requires a multifaceted, systems-based approach that integrates curricular innovation, professional practice exposure, effective assessment mechanisms, socio-cultural responsiveness, and continuous training. This empirically tested framework offers both academic and administrative stakeholders a strategic structure to guide implementation, evaluation, and refinement of online or hybrid pedagogical models in architectural education. While the present study has successfully identified and validated the foundational components of virtual pedagogy, future research could explore the interrelationships and hierarchies among these components using structural modelling techniques. Further studies could also apply this framework to postgraduate programs or international contexts to evaluate cross-cultural applicability. Additionally, longitudinal investigations may help assess how the adoption of virtual pedagogy evolves over time and influences student outcomes, professional readiness, and academic quality.

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