



An insight into architectural design studio education space from a "time" perspective

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Abstract

This study offers a comprehensive literature review of the evolution of design studio education, focusing on the integration of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) technologies. The research explores current and future design studio models by examining the development of architectural design studio education and the importance of its physical spaces within a timeline framework. The literature review identifies key insights, analyzes patterns, and integrates findings to present a narrative of architectural education's historical evolution and prospects. The study highlights significant shifts in design studio education, moving from the traditional master-apprentice relationship to contemporary design studio spaces within architecture schools. It emphasizes the impact of social, economic, and technological developments on these models, particularly the shift to remote education necessitated by COVID-19. This transition highlighted the need for alternatives to physical studio spaces, directing attention to VR, AR, and MR technologies as potential solutions. Through a meticulous review process, this study examines how these emerging technologies can provide immersive and interactive learning experiences, enhancing flexibility and accessibility in design education. It discusses the benefits and challenges of integrating these technologies, considering their potential to function without needing a specific physical studio. Ultimately, this study contributes to the field by offering theoretical insights and practical guidelines for educators. It explores alternative models to enhance adaptability and addresses the implications of technological adaptation and crisis management. The findings enrich the academic literature and foster future research and discussion on the evolution of design studio education in the digital era.

Keywords: the evolution of architectural design studio education, the future of architectural design studio education and its space, architectural design education, space of the architectural design education, quality education

1. Introduction

In contrast to conventional classroom settings, architectural design education studios are highly dynamic environments distinguished by activities such as sketching, creating models, engaging in discussions, and deliberations, all of which require critical, creative, and critical thinking processes. These characteristics highlight the unique role of studios in facilitating student learning (Dutton, 1991).

Architectural design education is unique and can be clearly distinguished from other fields due to its components, such as its pedagogy, people, tools, spaces, environments, and hidden contents, which create its own culture. Each component in the design studio education communicates and interacts with the others, and any change in one affects the others.

Significant factors have shaped and developed architectural and design studio education, ultimately forming the current structure.

The origins of this education can be traced back to the writings of Vitruvius during the years 30-20 BC, representing the earliest documented source on the subject (Costanzo, 2016). As

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architectural education continued to evolve, establishing the first school within the Royal Academy marked a pivotal moment (Barrell, 2013). This evolution also witnessed a shift in the location of design studios, moving from individual master's offices to becoming integral components of educational institutions, as exemplified notably by Ecole de Beaux (Griffin, 2019). The establishment of structured architectural education in the seventeenth century, driven by governmental regulations and societal values, initially followed a uniform model - the Beaux-Arts system in France (Salama & Wilkinson, 2007). The Bauhaus education laid the foundation for studio-centered design education, integrating architecture theory and practice in an interdisciplinary environment. Unlike the two-sectioned formal and practical structure of the Beaux-Arts, the Weimar Bauhaus School intertwined practical and theoretical studies, especially in the last three years. From 1930 to 1960, architecture schools worldwide adopted either the Beaux-Arts' separated ateliers and theoretical courses or the Bauhaus' integrated approach (Hacihasanoglu, 2019). Today, the lasting impact of Beaux and Bauhaus education and the tradition of design studios remains evident in contemporary architectural education.

The educational and spatial aspects of architectural studio education, which two educational models have influenced, have undergone continuous evolution and transformation due to technological advancements. The architectural academic community conducted extensive research on the computability of architectural design in the 1960s and early 1970s (Andia, 2001; Andia, 2002; Reffat, 2007). A significant transformation in design education and technology occurred with the introduction of computers and IT in the late 1980s. IT-related courses gained importance in architectural curricula, and by the 1990s, CAD and digital tools became essential in architecture, with many schools worldwide adopting these technologies (Reffat, 2007).

The advent of virtual reality offered entirely virtual environments, while more recently, extended reality (XR) has emerged (Reffat, 2007). Within the XR framework, virtual, augmented, and mixed-reality environments provide compelling alternatives to physical reality in design studio education. In today's rapidly advancing technological landscape, physical spaces undergo profound transformations as they become intertwined with alternative reality environments. This multidimensional and dynamic evolution has significant implications for various domains, including higher education, regarding research and spatial configurations.

Unexpectedly, during these technological developments and influences, the global COVID-19 pandemic in 2019 led to the widespread adoption of distance education across higher education institutions worldwide (IAU et al., 2020; Seeletso, 2022). The COVID-19 pandemic affected architectural education by shifting to remote learning, leading to challenges such as the absence of physical studio spaces, decreased peer engagement, and digital literacy issues. This emphasized the importance of active online learning communities and strategic planning to simulate the advantages of physical studios (Grover & Wright, 2020; Asfour & Alkharoubi, 2023).

In light of these historical developments, technological advancements, and unexpected disruptions, especially the COVID-19 process results, the subsequent sections of this paper explore the architectural design studio's journey with extended reality technologies within the technological advances. Extended technologies -virtual, augmented, and mixed realities- can enable design studio education without a physical studio, offering flexibility and access from anywhere.

Virtual Reality (VR) creates immersive digital environments for games, training, and education using devices like headsets. Augmented Reality (AR) overlays virtual objects in the real world, enhancing interaction in education and commerce with AR headsets. Mixed Reality (MR) combines VR and AR, allowing interaction with both environments, applied in engineering, healthcare, and education with devices like HoloLens (Salama, 2007).

In conclusion, the article illustrates and discusses the significant transformations that architectural design studio education has undergone up to the present day and examines the potential impact factors of today. Focusing on its future model regarding space and environment, particularly in light of the COVID-19 process, emphasizes the need to evolve this education.

Smart urban governance enhances the management and maintenance of green spaces using data-based technology and solutions as shown 2, such as:

1.1. Aim

The paper aims to underline the need for change and/or evolution within design studio education today. To achieve this, the study explores the historical and contemporary progression of Architectural Design Studio education, with a particular focus on the integration of emerging technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Through a comprehensive literature review and analysis of historical trends, the research seeks to identify significant shifts in design studio models, especially in the context of space and environment. The study highlights how these technologies can transform design education by providing flexibility and accessibility, addressing the challenges posed by the COVID-19 pandemic. Additionally, this research offers theoretical insights and practical guidelines for educators, fostering the evolution of design studio education to meet the demands of the digital era.

1.2. Methodology

This study utilizes a comprehensive literature review to discuss current and future design studio models by exploring the development of architectural design studio education and the importance of its physical spaces in a timeline framework. The process requires identifying appropriate literature, selecting relevant sources, extracting and combining key insights, analyzing patterns, integrating findings, discussing implications, and ultimately making conclusions. Through a meticulous approach, this study aims to thoroughly examine the historical progression of architectural education, the remarkable events influencing it, and its future potential, as well as discuss the recreation or renewal of design studio education and its models.

A methodical search was conducted across electronic databases, academic books, and academic journals using keywords such as “The Evolution and the Future of Architectural Design Studio Education and its Space, Architectural Design Education, Space of the Architectural Design Education” to gather relevant information. The review using these specified keywords included the most frequently repeated and prevalent events or influences in the evolutionary process. Then, in the literature review, efforts were made to access the primary sources most frequently referenced regarding these events and influences.

The selected studies' essential insights and findings were carefully reviewed. For the first phase, the reviews are focused on the thresholds of architectural education to create the historical timeline of the design studio education and its space framework. To seek the thresholds: “the first architectural education,” “the first architectural school,” “the first design studio,” etc., used to understand the evolution from two perspectives: how architectural education started, developed, and how this process reflected onto the educational space. The literature review focuses on this frame's repeated “the firsts” terms and extracts. The thresholds' historical timeline was concluded in 1919, and then the review continued by focusing on the factors affecting architectural education from 1919 to the present. For this phase of evolution, general reviews highlighted that from this period until now, it has been seen that the two design studio education models - *The Ecole des Beaux-Arts* (The first design studio space in architectural school) and *the Bauhaus (the first studio-oriented architectural design education)*- are continued in a general frame. Still, these models have had parallel changes depending on worldwide technological developments and dominant changes with the COVID-19 pandemic. So, for the second timeline, reviews focused on these developments and events. After all these reviews, as part of the technological advances and for the alternative model to distance education – *all architectural schools experienced-* the emerging technologies - *already started to influence architectural education and space parallel with the technological developments-* are foreseen as the continuation of this evolution. So, for the last reviews, the study focused on these technologies and architectural education. When the COVID-19 process necessitated the removal of the design studio from its physical space, the experiences of remote education indicated new pursuits for design studio education, highlighting the need for alternatives

to the physical space. Therefore, the review studies have focused on VR, AR, MR, and XR technologies, which hold the potential to offer alternatives to design education and its environment. The synthesized findings were then integrated to construct a comprehensive narrative of architectural education's historical evolution, current practices, and prospects. Drawing upon the synthesized findings, the study presents its conclusions, emphasizing key insights and identifying areas that warrant further research.

2. Evolution of Design Studio Education "Firsts"

2.1. The First Written Resource: Vitruvius, *The Ten Books on Architecture*, (Prob.) 30-20 BC

The earliest written resource on architecture is attributed to Vitruvius, a Roman architect who resided from approximately 80 to 10 BCE. In his publication "The Ten Books on Architecture," Vitruvius accentuates the significance of proficient architects in creating exceptional architecture. In his work "Elements of Architecture," Vitruvius presents the earliest known depiction of an architect's education and competencies. Vitruvius distinguishes between the practical and theoretical aspects of architecture. The practical facet, termed "fabrica," entails continuous and consistent practical experience, encompassing physical labor and utilizing fundamental materials guided by a design's depiction. Conversely, the theoretical aspect, known as "ratiocinatio," encompasses the capability to manifest and elucidate skillful creations founded on proportional principles (Pont, 2005).

According to Vitruvius, an architect's education necessitates an array of knowledge and diverse learning styles. This stems from the architect's responsibility to assess the works produced by other disciplines, thus rendering proficiency in various domains indispensable. Theory and practice both constitute pivotal constituents of an architect's education. Within architecture, two elements hold particular prominence: the object being denoted and the entity ascribing its meaning. The discussed subject is signified, while a demonstration grounded in scientific principles confers significance. Consequently, an architect ought to possess inherent talent and an inclination toward acquiring knowledge, as they must exhibit expertise in theory and practice. In conclusion, Vitruvius's work furnishes invaluable insights into the requisites of education and competencies for architects, highlighting the significance of theory and practice in pursuing exceptional architecture (Morgan & Warren, 1914).

Vitruvius's writings on architecture serve as a first and foundational guide, highlighting the essential balance between theory and practice in architectural education. Vitruvius emphasizes the multifaceted knowledge and skills necessary to create exceptional architectural works in the early times.

2.2. The First Academic Architectural Institution: *The Academie D'architecture*, 1671

The establishment of the Académie d'Architecture in France on December 3, 1671, marked the beginning of formal architectural education. It was the first institution dedicated to the comprehensive study of architecture and was established specifically to train aspiring architects. However, during the turbulent times of the late 18th century in France, the Academy was officially dissolved in 1793. Nevertheless, the legacy of architectural education it initiated was revived with the creation of the Beaux-Arts and continues to influence architecture schools worldwide to this day (Griffin, 2019).

Lectures at this academy were in mathematics, mechanics, construction, perspective drawing, and the science of fortification (Lueth, 2003; Weatherhead, 1941). Furthermore, the establishment and subsequent revival of architectural education in France, from the Académie d'Architecture to the École des Beaux-Arts, have left an enduring legacy that continues to shape architectural education worldwide, emphasizing the significance of its historical roots and the resilience of architectural pedagogy.

2.3. The First Design Studio: The Ecole des Beaux-Arts, 1819

The initiation of organized architectural instruction in the seventeenth century, propelled by governmental requisites and societal principles, initially adhered to a single archetype - the Beaux-Arts system in France (Salama & Wilkinson, 2007). This customary method of architectural education commenced with the establishment of the Ecole des Beaux-Arts in Paris in 1819, thereby introducing the design studio concept, which subsequently emerged as a fundamental pillar of formal architectural education across Europe, North America, and beyond (Anthony, 1991). The design studio, having endured for three centuries, has played a pivotal role in architectural education, constituting an essential component of contemporary design pedagogy (Salama & Wilkinson, 2007).

The design studio originates from the “atelier” within the Beaux-Arts education system as the primary means of instructing architects. Ateliers served as spaces for architecture students to engage in their work. The Beaux-Arts, a fine arts institution in Paris, served as a model for education adopted by numerous architecture schools in the nascent stages of architectural education (Anthony, 1991; Weatherhead, 1941).

The establishment of the Ecole des Beaux-Arts in 1819 introduced a groundbreaking paradigm for architectural education. This paradigm integrated design work within a studio environment supervised by experienced mentors. This pivotal development paved the way for the institutionalization of architectural education and profoundly influenced contemporary design pedagogy in France and beyond.

2.4. The First Design Studio-Centered Education: Bauhaus, 1919

Salama and Wilkinson assert that the dominant architectural education model for more than two centuries was the Beaux-Arts paradigm. However, in response to society's changing values in the late 19th century, the German Bauhaus model emerged as the sole alternative pedagogical approach before World War I. This emergence was a direct result of the technological advancements brought about by the Industrial Revolution. Despite their apparent disparities, both approaches emphasize architecture's formal and technical aspects, prioritizing the construction and dynamics of buildings, often neglecting social and cultural considerations (Salama & Wilkinson, 2007). Balamir notes that the Bauhaus education model strongly prioritized cultivating architectural creativity rather than replicating past masterpieces. The most significant distinction between the Bauhaus education and the Beaux-Arts model is that the former liberated students from strict technical constraints, highlighting the significance of creativity, imagination, and individual expression inherent in the arts (Balamir, 1985). The Bauhaus education can be seen as the foundation of a studio-centered design education, where architecture theory and practice are integrated in an interdisciplinary environment. In contrast to the two-sectioned formal and practical structure of the École des Beaux-Arts, the practical studies in material workshops of the Weimar Bauhaus School were closely intertwined with theoretical studies of color, composition, construction, and nature, particularly in the last three years of education. Between 1930 and 1960, schools of architecture in various countries adopted two different approaches: the two-sectioned formal practical structure of the École des Beaux-Arts, where ateliers were separated from theoretical courses, and the three-staged Bauhaus system, where practical and theoretical studies were integrated into ateliers (Hacihanoglu, 2019).

Essentially, the Bauhaus model, which emerged as an alternative to the longstanding Beaux-Arts paradigm, introduced a unique architectural education approach emphasizing creativity, imagination, and individual expression over technical conditioning. This shift in architectural pedagogy paved the way for greater artistic freedom and innovation.

3. Evolution of Design Studio Education & Space 1920 to 2019

The architecture profession can be traced back to the 3rd millennium BC when architects conventionally gained knowledge through apprenticeships for a prolonged period. However, in

recent times, this approach has been replaced by what is known as a "studio-based environment" (Glasser, 2000; Nanda & Solovyova, 2005). According to Bender and Vredevoogd (2006), modern learning studios share similarities with the studios of the French Royal Academy and the École des Beaux-Arts from the 19th century. In the industrialized world, design studios typically follow a consistent structure. Typically, students participate in weekly studio sessions where they receive guidance from a professor. These sessions usually take place in small groups. During these sessions, students are assigned to develop designs based on specific project briefs, which reflect real-world architectural tasks, and they receive regular feedback from their professors. Frequently, the design project itself serves as the primary assessment method for the studio, culminating in its presentation during the final "critique" session at the end of the semester, which is evaluated by a panel of experts (Bender & Vredevoogd, 2006). Stevens (1998) emphasizes that the design studio is widely recognized as the most distinctive and critical activity within the architectural curriculum (Crowther, 2013; Stevens, 1998). In design studios, semi-structured learning approaches, such as problem-based learning, are often employed (Crowther, 2013; Delahaye, 2005). This approach involves students working on design projects while tutors provide formative feedback through individual reviews during weekly classes. According to Biggs (1999) and Schön (1984), the primary mode of learning in studios is through dialogue, facilitating the development, elaboration, and enrichment of understanding (Biggs, 1999; Crowther, 2013; Schön, 1984).

The transition of design studio education from the apprenticeship model to the contemporary studio-based environment has positioned the design studio as the cornerstone of architectural education. This shift has fostered the implementation of semi-structured learning strategies and emphasized the importance of dialogue in enhancing students' understanding and creativity in architecture.

3.1. Evolution of Design Studio Education & Space with Technology 1950 to Ongoing Process

In the late 1950s, attempts were made to bridge the domains of architecture and computer science. These early initiatives were predominantly academic and arose from the problem-solving and systematic methods prevalent in the computer science community during the 1960s. The primary objective was to automate various aspects of architectural design to capture as much of designers' thought processes as possible. The architectural academic community conducted extensive research on the computability of architectural design throughout the 1960s and early 1970s (Andia, 2001; Andia, 2002; Reffat, 2007). Reffat describes a significant transformation in design education and technology, noting that architecture and architectural education underwent a substantial shift with the introduction of computers and information technology in the late 1980s. The integration of IT into architectural education is evident in the increasing importance of IT-related courses in architectural school curricula. In the 1990s, modern information technology and digital tools became essential in architecture and the profession. The field embraced computer-aided design (CAD) and became the primary working environment. Many architectural schools worldwide have adopted CAD and digital media (Reffat, 2007).

Crowther highlights changes in the architecture studio, observing that its informality distinguishes it. The physical space lacks a conventional front of the classroom. Instead, it includes movable furniture, sketching and drafting desks, model-making areas, computers, projection screens, and spaces for displaying models and drawings during critiques. The aim is to provide a flexible physical infrastructure to support adaptable teaching methods (Crowther, 2013; Taylor, 2008). Reffat notes that it has become common practice in many architecture schools for students to use notebook computers. The primary factors driving this approach are high enrollment numbers, limited physical space, and the costs associated with technical computing support and maintenance services. Advances in wireless networking technology, which enable mobility and access to the internet and network resources, have made this strategy more feasible for institutions and organizations (Reffat, 2007).

Furthermore, integrating technology into architectural education, particularly the adoption of computer-aided design and digital tools has fundamentally transformed the design studio environment. This transformation has resulted in flexible pedagogical spaces and the use of mobile technology, facilitating greater adaptability and connectivity within architectural education and practice.

3.2. Design Studio Timeless

Crowther (2013) argues that the term "studio" is widely employed in design, encompassing both a physical space dedicated to learning and teaching and a method of pedagogical engagement.

This concept parallels the notion of an artist's workspace, similar to an artist's studio. In many respects, the educational studio endeavors to replicate the professional studio environment by merging the physical setting with cultural and educational activities.

According to Akyildiz (2020), two distinct descriptions of a design studio highlight its multifaceted nature. First, it can be understood as a physical learning environment, serving as a fundamental unit of pedagogy and an approach to design education. Secondly, the studio is a climate where aspiring architects, individually or in groups, explore design challenges through experimentation. Collaborating with the studio instructor, they acquire the art of design in the process.

In contrast to conventional classrooms, Dutton (1991) emphasizes that studios are dynamic spaces in which students actively participate in activities such as drawing, model-making, discussions, and debates. These activities demand analytical, synthetic, and evaluative modes of thinking. The dynamism inherent in the studio setting underscores its unique position as an educational method.

The studio, as both a social and organizational context, provides an optimal atmosphere for refining the skill of discernment. This is of particular significance since architecture necessitates more than mere analysis and logical reasoning; it encompasses the capacity to create unified wholes from diverse, often elusive, components (Habraken, 2007). Dutton highlights that architectural education in most institutions during the 20th century has predominantly focused on design. Students may spend most of their time and effort in the design studio, which functions as a tangible outcome, materializing architectural concepts and a mode of thinking that amalgamates various aspects of architectural knowledge, possibilities, and limitations (Dutton, 1991).

The design studio is the foundation of architectural education, demanding a comprehensive comprehension of design studio pedagogy. Education is the fundamental basis of any design profession, and its approach and content play a crucial role in shaping adaptable built environments. It is imperative to approach this subject as a rich field of study, with its knowledge base, information, methodologies, tools, and procedures subject to examination and discussion (Crowther, 2013).

Salama and Wilkinson (2007) emphasize the significance of the design studio as a primary realm for students to explore and develop their creative abilities, which are greatly valued in architecture. They liken the design studio to a crucible, wherein students are shaped and molded.

A comprehensive examination conducted by the American Institute of Architecture Students (AIAS) task force in 2002 produced a report that provides definitions, insights, and recommendations regarding the culture of the design studio. According to the report, the design studio is a nurturing ground for students to cultivate critical thinking skills and challenge conventional norms to generate improved designs. Consequently, the studio courses and their corresponding environments foster the development of unique cultures that become deeply intertwined with the students' lives.

Improvement in studio pedagogies can sometimes be overlooked, hindering the effectiveness of teaching methods. The prevailing studio culture often manifests in normalized hierarchical

relationships, limited communication, and a preference for individual information consumption within a demanding atmosphere. These tendencies underscore the interconnectedness between education and broader societal processes, wherein social power dynamics influence knowledge distribution, selection, and arrangement. Within the design studio, this includes contemporary issues such as unequal relationships, class disparities, ethnic distinctions, and gender discrimination (Dutton, 1991).

Architectural design education's primary objective is cultivating students' imaginative capabilities. The core focus of this form of education is the design studio, where architectural design principles are imparted. While adhering to building regulations, students are encouraged to unleash their creative potential and generate novel concepts. These studios can be best understood as a well-structured and interconnected series of stages that span eight semesters, encompassing both the content taught and the methods employed for course delivery (Turgut, 2007).

At its most effective, the design studio sequence serves as a cohesive element that progressively connects the various components of architectural education. Encouragingly, several "integrative" studios have been identified where knowledge discovery, application, and design integration are actively explored (Dutton, 1991).

The design studio is a versatile and integral component of architectural education. The studio encompasses a physical space and a pedagogical strategy fostering creativity, critical thinking, and practical skills. It provides a dynamic environment in which students engage in diverse activities, promoting analytical, synthetic, and evaluative modes of thinking while also serving as a platform for developing the essential skill of sound judgment in architectural creation. The significance of the design studio in architectural education cannot be overstated, as it functions as a forge where students are shaped into imaginative thinkers and problem solvers. Nevertheless, it is crucial to recognize the need for continuous evaluation and enhancement of instructional approaches within the studio atmosphere to guarantee each student's comprehensive, fair, and productive learning setting.

4. Mandatory Break of Design Studio Education & Space Rapid Evolution, 2020-2021 Covid-19 Process

In light of the COVID-19 pandemic, numerous universities transitioned to remote learning, heavily relying on platforms such as Zoom, Google Hangouts, and Microsoft Teams (IAU et al., 2020; Seeletso, 2022). The primary modes of instruction became audio and video conferencing (Chan et al., 2023). Still, this shift presented various challenges, including the issues of digital literacy, infrastructure, engagement, confidentiality, and privacy (Wood-Harper, 2021). Research conducted on architectural education during the pandemic shed light on several key aspects:

- Asadpour observed how the pandemic disrupted the conventional approach to architectural design courses, presenting opportunities for examination and reform (Asadpour, 2021).

- Asfour et al. conducted surveys at a university in Saudi Arabia and found that while there were benefits in terms of time management and flexibility, challenges arose due to the absence of a group design studio atmosphere (Asfour & Alkharoubi, 2023).

- Grover and Wright discussed students' dissatisfaction with emergency remote learning in architecture, highlighting the difficulty of transitioning from a pedagogy rooted in physical spaces to an online format (Grover & Wright, 2023).

- Alnusairat et al.'s study revealed that participants expressed uncertainty regarding their online learning experiences and emphasized the need for more support and guidance. This uncertainty was attributed to personal circumstances, tutors' lack of experience with online teaching, and limited peer interaction (Alnusairat et al., 2021).

These findings underscore the significance of fostering vibrant online learning communities and peer-to-peer support in digital education. Converting studio-based teaching to online requires thoughtful planning (Grover & Wright, 2020).

Exploring alternative pedagogies is crucial for effectively delivering remote architectural education, even if adjustments are made to digital studios. While moving away from a pedagogy centered on physical spaces is essential, the effectiveness of alternative methods remains to be determined, particularly in replicating the social support provided by physical studios. Recreating intangible elements such as peer support digitally presents a challenge in online learning despite its potential to replace face-to-face interactions. The physical proximity, touch, and engagement integral to building a studio community and fostering lasting relationships significantly impact students' educational experiences and creative patterns (Grover & Wright, 2020).

Place-based pedagogy, supported by essential facilities, promotes educational equity. However, the absence of such resources can disadvantage students who rely on peer or tutor assistance, affecting their performance and well-being. Addressing this issue in the online learning environment is paramount, as it affects architecture schools with design studio traditions (Grover & Wright, 2020).

Blended learning presents a promising approach to enhancing in-person design studio classes by incorporating interactive online tools. This approach entails developing course materials and requirements for collaborative group projects and teamwork and improving existing digital educational platforms. However, it is essential to exercise caution and only partially substitute conventional teaching methods with online instruction, particularly in the initial stages of design study programs (Asfour & Alkharoubi, 2023).

The challenges encountered in architectural education are deeply rooted in conventional roles and curriculum content. A preliminary model known as Strategic Design Pedagogy (SDP) has been suggested to handle these challenges. However, despite efforts to transform tutors into facilitators and counselors, students are reluctant to participate actively in online design studios. Many significant solutions have been recommended to handle this matter. Firstly, short-term workshops and courses can assist students and professors in adapting to new circumstances and bridging the gap between existing knowledge and emerging challenges.

Furthermore, it is imperative to redefine the content, procedures, and learning outcomes of e-studio courses, focusing on enhancing communication skills and media literacy to facilitate effective student learning and assessment. Furthermore, when establishing new e-design studios and planning curricula, it is essential to consider factors such as peer support, emotional well-being, social interactions, and financial assistance. Strategic planning should also consider problems associated with seclusion, solitude, and the adverse effects of social media usage. In light of recent research highlighting the widening disparities between affluent and disadvantaged students in e-learning, structural adjustments should be made to accommodate limitations associated with national resources and university facilities. Finally, fostering global online connections among architectural institutions and leveraging the resources of other universities through virtual collaboration can promote empathy, bridge gaps, and facilitate the exchange of experiences (Adapted from Asadpour, 2021).

During the COVID-19 pandemic, architectural education has shifted from conventional in-person teaching to online distance learning, posing noteworthy challenges. While this shift has provided opportunities for examination and reform, it has also illuminated several challenges, such as difficulties with digital literacy, limitations in infrastructure, and the complexities of replicating the interactive studio environment online. Research conducted during the pandemic has underscored the significance of cultivating vibrant online learning communities and peer-to-peer support in digital education. A thoughtful and meticulous approach to converting studio-based teaching into an online format is essential, and exploring alternative pedagogical strategies is crucial for the successful delivery of remote architectural education. While blended learning methods hold

promise, they should supplement rather than supplant conventional teaching approaches, especially in the initial stages of design study programs. Furthermore, addressing disparities in resources and fostering global connections among architectural institutions can enhance the quality of online architectural education. As architectural education continues to adapt to the challenges of the digital era, these insights will play a pivotal role in shaping its future.

5. Evolution of Design Studio Education & Space with Emerging Technologies, Ongoing Process

Education strives to accomplish more than simply transmitting knowledge and skills; it aims to foster in students a passion for acquiring knowledge, effective collaboration, critical thinking, problem-solving abilities, adaptability in the face of unforeseen challenges, and an unwavering thirst for learning. This equips them to effectively apply their acquired knowledge, including digital literacy, in practical, real-world scenarios (Estes et al., 2021). The start of technology has dramatically affected higher education, completely changing the way teaching and learning occur. When strategically employed to align with educational objectives and standards, technology enriches the student experience and fosters meaningful engagement. Its combination comprises various elements of higher education, encompassing teaching, learning, curriculum design, and assessment (Alhazmi, 2021). Discussions and observations surrounding the transformation of conventional design studio education and its spatial elements have been ongoing since the early 2000s. There has been a significant increase in the number of research and development studies carried out in recent years, which coincides with the greater accessibility to technology. The ongoing discourse and observations regarding the transformation of conventional design studio education and its physical environment have persisted since the 2000s. The past few years have witnessed a surge in research and development endeavors, mainly due to the enhanced availability of technology (Salama & Wilkinson, 2007). The conventional design studio thrives in an environment that is dedicated and free from distractions.

Nevertheless, the introduction of modern technology has brought about significant disruptions, thereby challenging the efficacy of this model (Weiner, 2005). Architectural education has shifted away from the intensive and protracted studio format of the past, transitioning towards a more structured Bachelor/Master's degree system that aligns with other disciplines. To preserve its distinctive identity, architectural education must reevaluate this trend, as the studio serves as a privileged space for exploring both tangible and abstract facets of architecture (McQuillan, 2005). The influence of information technology on our lives has changed teaching methods and architectural design. Although technology allows immediate access to information, it lacks the sensory and physical encounters of the real world (McCann, 2005).

The improvement in computer-aided design (CAD), visualization, digital modeling, and data transmission technologies has made it feasible to include virtual elements in design education. Some argue that physical presence in a studio is no longer necessary, suggesting a departure from the conventional approach (Salama & Wilkinson, 2007). The emergence of virtual design studios (VDS) enables students from different locations to cooperate effectively in a computer-mediated environment. This transformation in studio format significantly impacts architectural education (Salama & Wilkinson, 2007). Despite the shift towards virtuality, the physical aspect of the studio remains essential, although it is now replaced by electronic means. Critics highlight the challenges of maintaining the studio's sanctity and the increasing trend toward individualization (Weiner, 2005).

Design pedagogy has embraced information technology, leading to the rise of paperless and virtual design studios. These studios prioritize digital design theory and practice (Salama & Wilkinson, 2007).

Architectural education examines fresh approaches to adjusting to the digital age using augmented reality and virtual learning environments. Students must learn to differentiate between virtual and real experiences critically. Design education should encourage students to consider the

significance of physical location and the value of hands-on experiences in an increasingly virtual world. Striking a balance between simulation and practical encounters is crucial in design education (Sorvig, 2005).

Distance learning frequently harnesses intelligent technology in education, offering advantages such as increased enrollment, efficient feedback mechanisms, and enhanced communication between students and educators through ubiquitous technologies. Nonetheless, it presents challenges such as the absence of face-to-face interaction, considerations regarding cost, the absence of a physical classroom, concerns surrounding privacy, and deliberations regarding the role of AI in human-centric activities (Chukwukelu et al., 2021).

Given the transformation in how students access information through technology, architectural education must adapt accordingly. Architecture programs now integrate digital technologies, particularly augmented reality (XR), in design education (Darwish et al., 2023). Evaluated with these improvements and unexpected shifts, extended Reality (XR), characterized by Gownder, incorporates the mix of genuine and virtual universes and the associations between people and machines encouraged by PC innovation and wearable gadgets. XR includes Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and the intersections between these realms (Darwish et al., 2023; Gownder et al., 2016). The inquiry posed by Sala and the subsequent response revolve around the suitability of virtual and augmented reality as instructional tools in classroom settings. While the answer might be affirmative, it is imperative to remember that not all educational environments derive advantages from implementing virtual and augmented reality (Sala, 2021).

Sala provides comprehensive definitions of virtual reality, augmented reality, and mixed reality, highlighting their distinctive characteristics, practical applications, and utilization within education (Table 1).

Table 1 The Criterion Identified in the Literature Review for Smart Urban Management of Green Spaces

	Virtual Reality	Augmented Reality	Mixed Reality
What is it?	digital environment that shut out the real world.	virtual objects overlaid on a real-world environment.	virtual environment combined with the real world
Features	closed and fully immersive. complete immersion in the VE. movement freedom in the digital atmosphere with sound effects.	open and partial immersive. real world enhanced with digital objects. digital on the real world.	interaction with both virtual and real environment. digital contents interact with the real world.
Applications	video games, training, collaboration, simulation, virtual worlds, edutainment.	video games, training, commerce, education, park themes, edutainment.	engineering, healthcare, education, edutainment.
Devices	data gloves, headset, special hand controllers	special AR headset	Microsoft Hololens, MR headset.
Application in education fields	can be used to enhance student learning and engagement.	can help make classes more interactive and allow learners to focus more.	touching and manipulating objects generates greater understanding, integrating with data sets, complex formulas etc.

As technology progresses, it becomes apparent that virtual reality (VR) can support these advancements, holding the promise of a positive future. When reflecting on VR's evolution from its inception to its current state of development, it is imperative to contemplate its journey, heightened accessibility, and potential for integration within the realm of education (Estes et al., 2021).

Sala furnishes a concise account of the historical progression of virtual reality (VR), augmented reality (AR), and mixed reality (MR) within the educational sphere as follows:

- 1989-1999: The initial endeavors to employ VR and AR in education.

- 2000-2010: The rapid advancement of electronic components improved the accessibility of VR and AR technology, facilitating their application in educational domains. MR began to gain popularity.

- 2011-2020: The continual refinement of VR, AR, and MR drives the expansion of their applications, bolstering interactivity and advocating for their utilization in teaching and learning (Sala, 2021).

As technological advancements continue, virtual reality (VR) holds great potential, particularly in education (Estes et al., 2021). In online settings, virtual worlds provide 3D representations of real objects or environments, whether realistic or fantastical and possess the capacity to influence communication significantly. Within the context of higher education, these 3D virtual worlds serve various purposes, such as facilitating virtual lectures (49%), discussions (32%), field trips (14%), simulations (28%), and gaming (11%). The existing literature typically backs the notion that conventional lectures in real-world settings yield superior results to those conducted in virtual environments. Seventeen primary categories of virtual environments are employed for educational purposes, including virtual classrooms, laboratories, meeting spaces, and replicas of actual locations. Guidelines have been established to harness these technologies for innovative teaching and learning methods. Utilizing virtual excursions within 3D virtual worlds proves viable for educational objectives, enabling students to explore sites across the globe (Ghanbarzadeh & Ghapanchi, 2021).

However, despite VR's potential for education, it encounters challenges such as limited device resolution, maintaining high frame rates on personal computers, and cost concerns, particularly in technical fields like architecture (Sala, 2021). Regarding the efficiency of 3D virtual universes in higher education, students' and educators' responses indicate that they can significantly improve learning results and offer valuable alternatives to conventional classes. This assertion is supported by existing literature (Ghanbarzadeh & Ghapanchi, 2021).

Design schools may need to revisit curricula and provide more hands-on experiences as we navigate the information age. The rise of the virtual world emphasizes the importance of tangible skills and material creation (Sorvig, 2005).

In the face of an increasingly virtual world, design education must find a balance and reinforce the value of tangible and material experiences (Sorvig, 2005).

To summarize, incorporating emerging technologies, specifically Extended Reality (XR), in higher education fundamentally alters how students engage with educational materials. Technology has become a dispensable tool for enhancing the student learning experience, facilitating meaningful interaction, and accommodating the changing demands of modern education. The utilization of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) within educational contexts, coupled with the restructuring of conventional design studio education, underscores both the promise and obstacles associated with technological progress in education. These technologies, along with space-time tools and methods, hold the potential to conduct design studio education without the need for a specific physical studio. This approach allows for greater flexibility and accessibility, enabling students and educators to interact with design concepts and collaborate from any location at any time. Furthermore, as we navigate the ever-changing educational landscape in the digital era, it is evident that technology will be pivotal in shaping the trajectory of higher education, providing students with the essential skills, adaptability, and digital literacy required to thrive in an increasingly dynamic world.

6. Conclusion and Discussion

This study explores the evolution of design studio education with its firsts. It presents crucial shifts in design studio education, instruction method, and space, such as transitioning from the master's place/space to the contemporary design studio space within architecture schools (Table 2).

Table 2 Evolution of Design Studio Education Instruction and Design Studio Education Space by Time

Time	Design Studio Education Instruction	Design Studio Education Space
Before 1671	master-apprentice relationship	master’s place, site, built environment
Between 1671-1819	master-apprentice relationship	master’s place
1819 - Beaux	architecture practice experienced master/ instructor-student as an apprentice	design studio in school
1919 - Bauhaus	instructor- student as apprentice	design studio in school
1919-2019	instructor- student as apprentice	design studio in school
2019-2021	instructor- student as apprentice	online design studio (zoom, teams etc.)
2021-2022	instructor- student as apprentice	design studio in school
2023-...	instructor- student as apprentice?	alternative environments?

From its firsts until 2019, architectural design studio education was predominantly influenced by the globally acknowledged Beaux and Bauhaus architectural design education models (Figure 1).

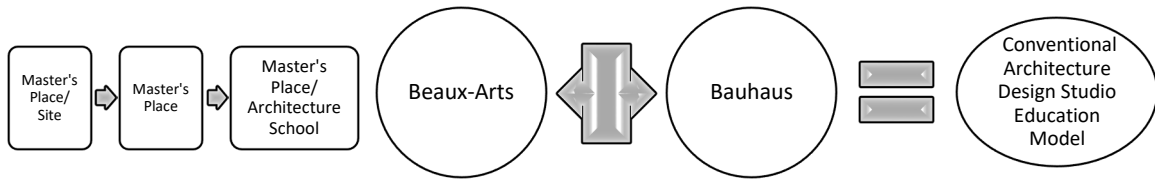


Figure 1 Conventional architectural design studio education model formation diagram

In these design education models, especially Bauhaus, design studio education has a structure that goes far beyond just being education in a studio space; it encompasses a diverse history and a variety of dynamic components. People, pedagogy, tools, spaces, and hidden content establish the basis of the design studio as its components. Each component interacts and communicates with the others, indicating that alterations in one can impact all others (Table 3).

Table 3 Design Studio Education Components

Architectural Design Studio Education & Culture Components	Contents of each Component
People	students, instructors, jury, other students around, and other people around, etc.
Pedagogy	methods, approaches, theories, syllabus, curriculum, etc.
Tools	papers, pencils, notebooks, computers, tablets, models, model materials, tables, chairs, boards, screens, clipboards, etc.
Spaces	studio, school, campus, site, built environment, daily-life students’ spaces, etc.
Hidden Content	actions, interactions, socializing, encounters, ambiance, discussions, everyday experiences, learning from the environment, peer relations, synergy, etc.

Social, economic, and technological developments have significantly altered the components, especially the tools of the two conventional design studio education models by the period. Particularly concerning the technological impacts, the emergence of portable computers and tablets has rendered it feasible to operate from various locations, introducing an aspect of adaptability to the design studio space. This technological transition has not merely affected the outfitting and adaptability of these spaces but has also redefined what constitutes a design studio again (Figure 2).

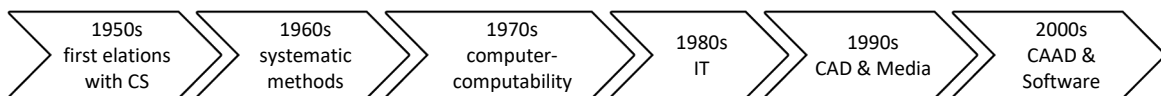


Figure 2 Computer science development and architectural design education interaction process

However, as developments continue, the most notable factor accentuating the need for the conventional design studio education—which has persisted for more than two centuries based on

two primary models and whose components generally exhibit resemblances across numerous design studio educations worldwide—to evolve and hasten technological assimilation has been the architectural education experience encountered during the COVID-19 process. The COVID-19 crisis prompted an abrupt transition to remote education in architectural education, leading to significant changes. This transition made video conferencing, digital equipment, and social media platforms indispensable. Traditional design studio environments were shifted to digital spaces, and course materials and equipment were reorganized for online education. However, these changes in the environment and the associated tools led to differences compared to traditional face-to-face design education. Online design studio education could not achieve the same learning and teaching outcomes as face-to-face education. In the process, perhaps just changing the conventional design studio environment has led to differences in each education component and, consequently, in learning outcomes. This situation underscored the necessity to evaluate online and remote education and highlighted the importance of each component within the educational framework. Therefore, the need for alternative design studio education in different conditions and environments, and considering the interaction and content of its components while analyzing these alternatives, was found to be of vital importance. As the educational system reverts to normalcy after the crisis episode, the question of how architectural design studio education can be organized beyond technological measures and a studio setting for the present and future has commenced to be re-evaluated with all its components. In this context, alternative realities and their technologies have gained significance for creating another design studio education model or re-novating conventional design studio education models.

Given the current developments (Figure 3), integrating or shifting VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality) technologies into design studio education has the potential to provide immersive and interactive learning experiences beyond traditional methods. Each technology can offer the design studio's education and environment different opportunities.

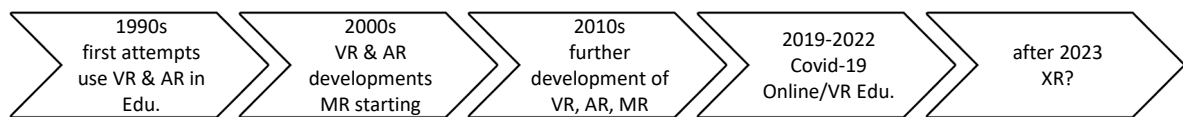


Figure 3 VR, AR and MR technologies developments and their educational usage process

VR can establish a fully immersive digital design studio. Learners can utilize VR headsets to enter a virtual realm, engaging with 3D representations of their designs. This enables a more profound comprehension of spatial connections and the consequences of design choices. VR studios can replicate real-life scenarios, allowing students to explore their designs at actual size and from various viewpoints. Virtual collaboration areas can also link learners and educators from diverse locations, fostering cooperation and input. An advantage of VR is its potential to eliminate the necessity for a physical design studio venue, as the immersive setting can be accessed from any location equipped with the required technology.

AR improves the physical design studio by layering digital elements onto the real world. Using AR eyewear or mobile gadgets, scholars can observe virtual components overlaid on their physical models or studio spaces. This proves valuable for site assessment, where digital facts regarding site conditions can be superimposed on a physical model. AR can also enable interactive demonstrations, with lively visual representations responding to user engagement. While AR typically enhances an existing physical setting, it can be applied in diverse environments, be it enclosed, open, or partially open spaces, providing adaptability in design studio tasks.

MR merges VR and AR, allowing students to engage with physical and digital entities concurrently. In an MR design studio, learners can manipulate virtual models manually while remaining conscious of the physical studio setting. This technology promotes collaborative efforts, permitting multiple users to engage with the same digital entities from separate locations. MR can

also integrate real-time information and simulations into the design procedure, providing comprehensive insight into design repercussions. MR allows versatility to function in various settings, whether enclosed, open, or partially open, providing a flexible approach to executing design studio tasks.

These technologies can substantially diminish the dependence on conventional physical design studios. Scholars can access design studio education from any location with the necessary equipment and internet connectivity, boosting accessibility and enabling a broader spectrum of participants.

As a result, this study contributes to the field by providing a comprehensive analysis of the evolution of design studio education and the integration of VR, AR, and MR technologies. It offers educators theoretical insights and practical guidelines and explores alternative models to enhance flexibility and adaptability. Additionally, it addresses technological adaptation and crisis management, enriching the academic literature and fostering future research and discussion.

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Note

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