Ayşegül Kidık

Ph.D. Thesis

JULY 2024

XR (EXTENDED REALITY) IMPACT ON ARCHITECTURAL DESIGN EDUCATION

A THESIS
SUBMITTED TO THE DEPARTMENT OF ARCHITECTURE
AND THE GRADUATE SCHOOL OF ENGINEERING AND SCIENCE OF
ABDULLAH GUL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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SCIENTIFIC ETHICS COMPLIANCE

I hereby declare that all information in this document has been obtained in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

Ayşegül KIDIK

REGULATORY COMPLIANCE

The Ph.D. thesis, XR (Extended Reality) Impact on Architectural Design Education, has been prepared according to Abdullah Gul University's Graduate School of Engineering & Science Thesis Writing Guidelines.

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ACCEPTANCE AND APPROVAL

Ph.D. thesis titled XR (Extended Reality) Impact on Architectural Design Education, prepared by Ayşegül Kıdık, has been accepted by the jury in the Architecture Graduate Program at Abdullah Gül University, Graduate School of Engineering & Science.

22/07/ 2024

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ABSTRACT

XR (EXTENDED REALITY) IMPACT ON ARCHITECTURAL DESIGN EDUCATION

Ayşegül KIDIK
Ph.D. in Architecture
Advisor: Prof. Burak ASİLİSKENDER

July 2024

The "XR (Extended Reality) Impact on Architectural Design Education" dissertation comprehensively examines the integration and impact of Extended Reality (XR) technologies in architectural design experience. As the field of architectural design education struggles with the challenges presented by technological advancements, this research endeavors to explore the potential of XR technologies, which encompass Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), to redefine the design process and enhance the creative capacity of architecture students.

In the rapidly evolving landscape of contemporary architecture, architectural design education is paramount in fostering future architects equipped to meet the dynamic demands of the profession. XR technologies have emerged as transformative tools that have the potential to revolutionize how architects engage with their projects, offering immersive and interactive environments for design exploration that have different realities.

The methodology employed in this research is varied, combining comprehensive and systematic literature reviews with empirical case studies. This methodological synergy integrates theoretical insights from literature reviews with practical observations from real-world architectural projects, facilitating a comprehensive exploration of XR technologies within the context of architectural design studio education.

The literature review encompasses a wide range of topics, including architectural design studio education, the fundamental principles of XR technology, and emerging trends in architectural education. These reviews provide the requisite theoretical framework for comprehending the implications of XR technologies on the design experience.

Within the dissertation, systematic literature reviews are conducted on VR, AR, MR, and XR technologies, thereby shedding light on their integration into architectural design studio education. These reviews synthesize existing research findings, identify key trends, and address the challenges and opportunities associated with each technology.

A case study approach offers a practical perspective, investigating real-world architectural projects and design studios embracing XR technologies. Through these case studies, the intricacies of XR integration are explored, the transformative effects on design experience are assessed, and exemplary practices in architectural design are showcased.

Moreover, the dissertation discusses XR technologies in relation to conventional design education, thereby underscoring their potential to redefine architectural pedagogy.

This research explores integrating XR technologies into architectural education to enhance students' creative capacities and redefine the design process. By incorporating XR technologies, architecture students gain the skills and knowledge necessary for sustainable development, fostering innovation, sustainability, and technological proficiency. XR technologies in education provide a quality learning experience that aligns with global sustainability goals, preparing students to contribute effectively to the achievement of Quality Education (Sustainable Development Goal 4).

This research contributes to the ongoing discussion on the role of technology in shaping the future of architectural design education and practice. It sheds light on the transformative potential of XR technologies in architectural design education. Architects, educators, and students stand to gain valuable perspectives on harnessing XR technologies to enhance creativity and innovation in the architectural field.

Keywords: XR (Extended Reality), VR (Virtual Reality), AR (Augmented Reality), MR (Mixed Reality), architectural design studio education, design experience, quality education (SDG-4)

ÖZET

GG (GENİŞLETİLMİŞ GERÇEKLİK)'İN MIMARİ TASARIM EĞİTİMİNE ETKİSİ

Ayşegül KIDIK
Mimarlık Anabilim Dalı Doktora
Tez Danışmanı: Prof. Dr. Burak ASİLİSKENDER

Temmuz 2024

"GG (Genişletilmiş Gerçeklik) Teknolojilerinin Mimarlık Tasarım Eğitimi Üzerindeki Etkisi" başlıklı tez, mimarlık tasarımı deneyiminde Genişletilmiş Gerçeklik (GG) teknolojilerinin entegrasyonu ve etkisini kapsamlı bir şekilde incelemektedir. Mimarlık tasarımı eğitimi alanı, teknolojik ilerlemelerle ortaya çıkan zorluklarla mücadele ederken, bu araştırma, Sanal Gerçeklik (SG), Artırılmış Gerçeklik (AG) ve Karma Gerçeklik (KG) gibi GG teknolojilerinin tasarım sürecini yeniden tanımlama ve mimarlık öğrencilerinin yaratıcı kapasitesini artırma potansiyelini keşfetmeyi amaçlamaktadır.

Çağdaş mimarlık dünyasında hızla gelişen ortamda, mimarlık tasarımı eğitimi, mesleğin dinamik taleplerini karşılamaya hazırlıklı geleceğin mimarlarını yetiştirmek açısından büyük önem taşımaktadır. GG teknolojileri, mimarların projeleriyle etkileşim kurma biçimini devrim niteliğinde değiştirme potansiyeline sahip, sürüykleyici ve etkileşimli tasarım keşif ortamları sunan dönüşüm araçları olarak ortaya çıkmıştır.

Bu araştırmada kullanılan metodoloji çeşitlidir ve kapsamlı ve sistematik literatür incelemeleri ile ampirik vaka çalışmalarını birleştirmektedir. Bu metodolojik sinerji, teorik literatür incelemelerinden elde edilen içgörüleri, gerçek dünyadaki mimari projelerden elde edilen pratik gözlemlerle birleştirerek, mimarlık tasarım stüdyosu eğitimi bağlamında GG teknolojilerinin kapsamlı bir şekilde keşfedilmesini sağlar.

Literatür incelemesi, mimarlık tasarım stüdyosu eğitimi, GG teknolojisinin temel prensipleri ve mimarlık eğitimindeki gelişen trendler gibi geniş bir konu yelpazesini kapsar. Bu incelemeler, GG teknolojilerinin tasarım deneyimi üzerindeki etkilerini anlamak için gerekli teorik çerçeveyi sağlar.

Tezde, SG, AG, KG ve GG teknolojileri üzerine sistematik literatür incelemeleri yapılmaktadır ve bu incelemeler, bu teknolojilerin mimarlık tasarım stüdyosu eğitimine entegrasyonuna ışık tutar. Bu incelemeler mevcut araştırma bulgularını sentezler, anahtar trendleri belirler ve her bir teknolojinin beraberinde getirdiği zorluklar ve fırsatları ele alır.

Vaka çalışması yaklaşımı, GG teknolojilerini benimseyen gerçek dünya mimari projeleri ve tasarım stüdyolarını inceleyerek pratik bir perspektif sunar. Bu vaka çalışmaları aracılığıyla, GG entegrasyonunun karmaşıklıkları incelenmekte, tasarım deneyimi üzerindeki dönüşümsel etkiler değerlendirilmekte ve mimarlık tasarımında örnek teşkil eden uygulamalar sergilenmektedir.

Ayrıca, tez, GG teknolojilerini geleneksel tasarım eğitimi ile ilişkilendirerek, bunların mimarlık pedagojisini yeniden tanımlama potansiyelini vurgular. Bu araştırma, GG teknolojilerinin entegrasyonunun öğrencilerin yaratıcı kapasitelerini artırma ve tasarım sürecini yeniden tanımlama yollarını araştırır. GG teknolojilerini kullanarak, mimarlık öğrencileri sürdürülebilir kalkınma için gerekli becerileri ve bilgileri kazanır, yenilikçiliği, sürdürülebilirliği ve teknolojik yeterliliği teşvik eder. Eğitimde GG teknolojileri, küresel sürdürülebilirlik hedefleriyle uyumlu kaliteli bir öğrenme deneyimi sağlar ve öğrencileri, Kaliteli Eğitim (Sürdürülebilir Kalkınma Hedefi 4) hedefine etkin bir şekilde katkıda bulunmaya hazırlar.

Bu araştırma, teknolojinin mimarlık tasarım eğitimi ve pratiğinin geleceğini şekillendirmedeki rolü konusundaki devam eden tartışmalara katkıda bulunur. GG teknolojilerinin mimarlık tasarımı eğitimindeki dönüşüm potansiyelini aydınlatır. Mimarlar, eğitimciler ve öğrenciler, GG teknolojilerini kullanarak mimarlık alanında yaratıcılığı ve yeniliği artırma konusundaki değerli perspektiflerden yararlanır.

Anahtar Kelimeler: GG (Genişletilmiş Gerçeklik), SG (Sanal Gerçeklik), AG (Artırılmış Gerçeklik), KG (Karma Gerçeklik), mimari tasarım stüdyosu eğitimi, tasarım deneyimi, kaliteli eğitim (SDG-4)

Acknowledgments

I would like to express my profound gratitude to Prof. Dr. Burak Asiliskender, my thesis advisor, for his unwavering support, expertise, and constructive critiques throughout my research and studies. His invaluable guidance has played a significant role in the progress and success of this research.

I extend my heartfelt thanks to Prof. Dr. Tugay Kerem Koramaz for his critical and strategic insights as a member of my thesis monitoring committee. His developmental feedback has significantly enhanced the quality of my work.

I am sincerely thankful to Assoc. Prof. Togan Tong for sharing his extensive knowledge and experience, which has been crucial in guiding my research in the right direction.

This thesis was supported by the TÜBİTAK 2214-A International Research Fellowship Program for PhD Students. I am grateful to TÜBİTAK for their financial, procedural, and moral support. Additionally, this research was supported by the YÖK 100/2000 Doctoral Program. I extend my thanks for their support.

I am deeply grateful to those who have supported and contributed to developing my research fellowship at the University of Central Florida. My sincere thanks are to my research advisor, Assoc. Prof. Dr. Scott Branting, for his invaluable guidance, direction, and contributions. I also appreciate Assoc. Prof. Dr. Joseph Kider, for his expert approach and for facilitating research discussions throughout the process, greatly aided my progress. I am indebted to Res. Assoc. Prof. Lori C. Walters, Post Doc. Robert A. Michlowitz, and my dear friends Jeralyn P., Joslyn P., Jessica R., Dominique L.-B., Lauren D., John S., Emily P., and Malic D. for sharing their perspectives, knowledge, and experiences from their respective fields, and for engaging in discussions about research.

I want to extend my sincere gratitude to the dedicated students who participated as volunteers in the case study and generously shared their experiences. Their contributions and commitment have been invaluable to this research.

I wish to extend my sincere gratitude to the members of my thesis defense committee, Assoc. Dr. Buket Metin and Assoc. Dr. Aktan Acar, for their invaluable time, insightful feedback, and esteemed recommendations concerning my thesis.

I am also grateful to my colleagues and students at AGÜ for their encouragement.

To my beloved family—my father, mother, brother Salih, sister Nihal, my dear niece Alara, and nephew Emre—I am deeply grateful to have you in my life…

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LIST OF ABBREVIATIONS

ADSE	Architectural Design Studio Education
ADE	Architectural Design Education
AE	Architectural Education
AEC	Architecture, Engineering, and Construction
AGU	Abdullah Gul University
AR	Augmented Reality
ASES	Architectural Spatial Experience Simulation
BD	Basic Design
DSE	Design Studio Education
FPS	First-Person Shooter
GDD	Game Design Document
HE	Higher Education
IVR	Immersive Virtual Reality
MDL	Model of Domain Learning
MR	Mixed Reality
NPC	Non-Player Character
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
SDP	Strategic Design Pedagogy
ST	Student
UI	User Interface
UX	User Experience
XR	Extended Reality
VAM	Virtual Augmented Mixed
VE	Virtual Envrionment
VIO	Visual Inertial Odometry
VR	Virtual Reality
WASD	Keyboard Keys to Move (W: forward, A: left, S: backward, D: right)
3DVW	Three-Dimensional Virtual World

To my father, 2024

Chapter 1

Introduction

In architectural instruction, the pursuit of innovative and successful teaching methods is constantly evolving in response to the profession's changing demands and the dynamic nature of contemporary design practices. Architectural education is grounded in design studios, where students can enhance their creativity, critical thinking, and design skills. As the field of architecture evolves with the integration of emerging technologies, it is imperative for architectural education to adapt accordingly, leveraging powerful tools such as XR (Extended Reality) technologies—including virtual, augmented, and mixed reality—to equip future architects for the demands of a technology-driven world.

XR technologies have demonstrated their ability to transcend conventional teaching methods by offering immersive and interactive environments that enable students to explore and experiment with architectural concepts in previously unattainable ways. These technologies can enhance the educational experience by allowing students to visualize, manipulate, and engage with architectural spaces and designs in real time.

Chapter 2 of this thesis examines the evolution of architectural design studio education over time to identify the factors influencing this transformation. The development process has been considered from its inception to the present day, and the factors that have shaped its current state have been evaluated. The comprehensive literature review has shown that societal and technological developments have significantly impacted the thresholds that design studios have experienced over time. Today, it is possible to suggest that XR technology, which has gained substantial importance, especially in the post-COVID era, could represent the next threshold in design studio education. This chapter aims to provide valuable insights into the outcomes, challenges, and opportunities of integrating these advanced technologies into design studio education by synthesizing existing knowledge and systematically examining virtual, augmented, mixed, and extended reality technologies.

In Chapter 3, research on XR technologies and design studio education, particularly focusing on studies from the last five years, is analyzed due to the current state of technology and the increased importance of these technologies in the post-COVID-19 era. These studies reveal the strengths, weaknesses, areas for improvement, and potential of XR technologies in architectural design studio education. However, the literature review also shows that studies integrating VR, AR, and MR technologies in a complementary framework are quite limited, with existing studies often focusing solely on the experience of new technologies, either with or without control groups. Therefore, the case study presented in the following section is designed to fill these gaps and contribute to the literature by developing a concept that addresses these shortcomings.

In Chapter 4, integrated fictions were developed for the case study to use XR technologies for design studio education. In this context, first, a video game was designed and implemented to embed architectural knowledge within the game. The purpose of this game is to help students understand this knowledge before starting their design work, raise their awareness, and stimulate their curiosity through gameplay—which would lead them to further research after playing the game—while also facilitating visual and experiential learning and preparing them to design in XR environments. In conventional design studio education, this process is typically achieved through literature review lists, topics, project research, and technical research recommendations provided to students in the first week of the course. However, in this study, the aim is to conduct these processes digitally through gameplay.

Secondly, a system was set up to enable students to design in VR and AR environments using screens and VR/AR headsets, allowing them to choose whether to design in VR or AR environments. The Arkio platform - a cloud-based platform developed for architects and designers, enabling 3D modeling and collaboration in virtual reality (VR) and augmented reality (AR) environments, allowing users to create, edit, and interact with projects in real time was used for this process. In this setup, students experience design using these tools.

Due to the lack of a similar platform or software that could be used with MR environments and tools, the research focused on comparing conventional design studios with VR and AR environments and tools (video game + screens, video game + VR/AR headset; both screens and headsets providing either VR or AR environments, depending on the students' preferences). The case study was designed to compare different environments and tools and assess their impact on the design experience, process, and outcomes. This empirical investigation provides evidence of the benefits and challenges of adopting extended reality technologies, offering insights into their effectiveness as design studio educational tools.

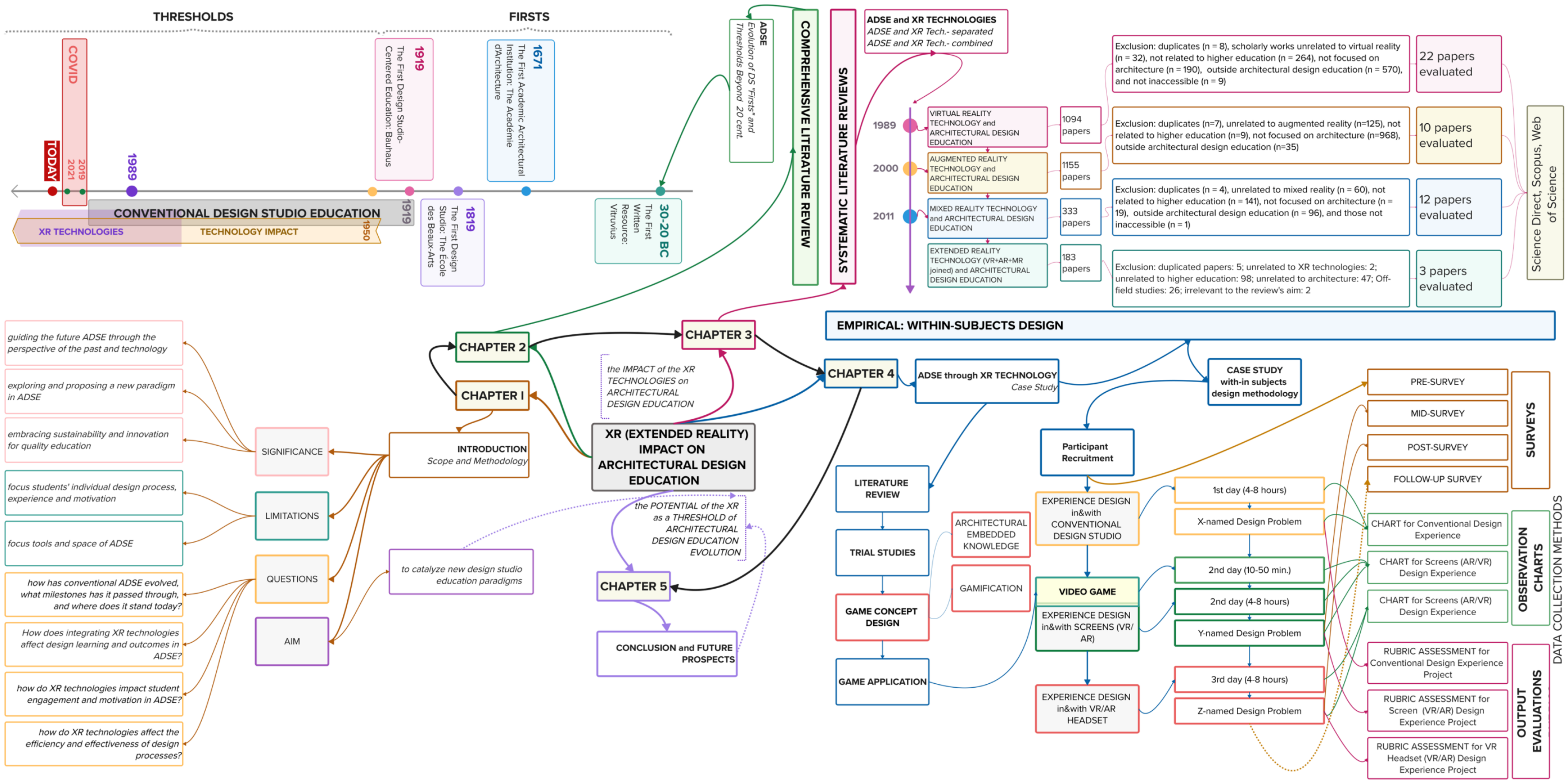
The scope of the case study was limited to a small number of students due to the constraints on the number of devices and the process required for the experience. Therefore, a call for voluntary participation was made exclusively to AGU Architecture students at the 2nd, 3rd, and 4th levels. Three design problems were prepared for each environment, all of which are similar in small scale and relatively uncomplicated. A time frame of 4-8 hours was allocated for each task, considering that all the students had already completed their basic design education. The within-subjects design method was selected, allowing students to serve as their own control group, enabling them to design individually in three different environments and compare their experiences. A tripartite data set was envisioned in this study to implement this method and strengthen the accuracy of the findings. This data set involves collecting information through open and closed-ended questionnaires regarding students' experiences, using observation charts designed by the researcher during the design process, and evaluating the design products using rubrics.

In Chapter 5, it has been concluded that, as indicated by the comprehensive literature review, supported by systematic literature analyses, and evidenced by the results of the case study, XR technologies have the potential to facilitate the evolution and transformation of architectural design studio education. All studies highlight XR technologies' positive and negative aspects and areas that require further development, providing valuable insights to guide future research. Additionally, this research examines the broader societal implications of integrating XR technologies into architectural education, emphasizing their potential contributions to global sustainability and design innovation.

The primary goal of this research is to advance the current discourse on the role of extended reality technologies in shaping the future of architectural design studio education. Ultimately, this research aims to provide valuable insights for educators, students, and professionals in the field. This thesis contributes to academic knowledge and seeks to illuminate the path toward a more immersive, dynamic, and effective paradigm in architectural education.

The thesis map is presented on the subsequent page to guide the readers (Figure 1.1).

Figure 1.1 Thesis Map.



1.1. Research Scope

The primary goal of the thesis is to comprehensively examine the integration and impact of extended reality technologies in architectural design studio education, thereby creating a discussion for future design studio education models. The research provides an in-depth understanding of how these emerging technologies can be effectively utilized in this field and emphasizes their transformative impact on education. The research scope is shaped around the research questions and objections as below (Table 1.1).

Table 1.1 Research questions, objectives, and assumptions.

Research Questions	Objectives	Assumptions
how does integrating XR technologies (VR, AR, MR) affect the design learning experience and outcomes in architectural design studio education (ADSE) compared to conventional ADSE?	to investigate the integration, effectiveness, and challenges of Extended Reality (XR) technologies within architectural design studio education, aiming to provide insights for enhancing pedagogical practices in the field.	integrating XR technologies (VR, AR, MR) in architectural design studio education (ADSE) enhances design learning experience and outcomes compared to conventional education.
how do XR technologies impact student engagement and motivation in ADSE?	to examine the diverse impacts of Extended Reality (XR) technologies on design education experiences, including their influence on student learning outcomes, pedagogical approaches, creative processes, and overall engagement within educational settings.	XR technologies positively impacts student engagement and motivation.
how do XR technologies affect the efficiency and effectiveness of design processes?	to investigate and analyze the impact of Extended Reality (XR) technologies on design experiences, encompassing spatial perception, creativity, user engagement, and the overall design process, with the aim of providing insights into leveraging these technologies to optimize design outcomes and foster innovation.	XR technologies in ADSE enhance real-time visualization, contributing to more effective and motivated design processes.

The study previously carried out a comprehensive literature review that examines the formation of design studio education through its "firsts" and its development over time to the present day. It emphasizes that the design studio is on the threshold of a new transformation due to contemporary developments. It suggests that this transformation can be achieved through the potential of XR technologies.

Second, the thesis conducts systematic literature reviews on VR, AR, MR, and XR technologies to establish a strong theoretical framework for understanding their potential.

The goal is to synthesize existing research findings, identify key trends, and address the challenges and opportunities associated with each and combined technology.

Third, through empirical case studies, the thesis aims to provide practical insights into real-world architectural design projects and design studios embracing XR technologies. It explores the intricacies of XR integration, assesses the transformative effects on design experience, and showcases exemplary practices in architectural design education.

Finally, the conclusion section discusses the potential and predictions for the conventional design studio, which has evolved through its milestones and transformative thresholds from its inception to the present, to enter a new phase or transformation threshold with the integration of XR technologies.

1.2 Research Methodology

The thesis method consists of three methodologies (Table 1.2):

- A comprehensive literature review is conducted for Architectural Design Studio Education (2nd Chapter).
- Systematic literature reviews are executed for Architectural Design Studio Education and Extended Reality Technologies (3rd Chapter).
- The empirical case study is applied -uses a within-subjects design methodology- for design experience with XR technologies (4th Chapter).
- Overall evaluation of all chapters for future prospects (5th Chapter).

Table 1.2 Overview of the Research Methods**.**

Methodology	Aim	Outcome
compherensive literature review	synthesizing key findings, identifying emerging trends, and establishing the theoretical framework for the study.	establish a theoretical basis on Architectural Design Studio Education and Extended Reality Technologies.
systematic literature review	to identify patterns, recurring themes, and gaps in the existing literature; this analysis provided insights into the distinct characteristics and contributions of VR, AR, MR, and XR technologies to architectural design experience.	comprehensively reviews the existing body of knowledge on each XR technology (VR, AR, MR, and XR) in the context of architectural design experience.
within-subject design research	to evaluate the impacts of XR technologies in design education, within-subjects individually.	measures the impacts of XR technologies on design education by minimizing individual differences, provides valuable insights for developing educational strategies and integrating innovative approaches.

The first chapter of this dissertation focuses on laying the groundwork for understanding the intersection of architectural design studio education and extended reality (XR) technologies. Through an exploration of research scope and methodology, the foundational framework for this study is established, delineating the parameters within which the subsequent analysis unfolds.

Chapter Two investigates the landscape of architectural design studio education, examining its conventional methodologies and contemporary challenges. By contextualizing the evolving nature of design pedagogy, this chapter sets the stage for a deeper exploration of the integration of XR technologies.

Chapter Three shifts the focus toward XR technologies, providing an in-depth examination of Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and Extended Reality (XR). Through a comprehensive exploration of these immersive technologies, their fundamental principles and applications within architectural education are elucidated, paving the way for a nuanced understanding of their potential impact. This chapter emerges as a pivotal juncture, wherein the synthesis of architectural design studio education and XR technologies takes center stage. Through a series of subchapters, including discussions on VR, AR, and MR, the integration of XR technologies within design pedagogy is scrutinized, highlighting their transformative potential.

Chapter Four presents a detailed case study, offering a real-world exploration of XR technologies in the context of architectural design education. This chapter provides insights into the practical implications of integrating XR technologies within design studios by delineating the case study's aim, scope, methodology, and result.

Finally, Chapter Five draws upon the accumulated knowledge and findings to formulate conclusive remarks and outline prospects. By examining societal impact, contributions to global sustainability, and future trajectories, this chapter encapsulates the overarching implications of the research findings, offering a roadmap for future endeavors in architectural education and XR technologies.

Chapter 2

Architectural Design Studio Education

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 architectural education continued to develop, establishing the first school within the Royal Academy marked a pivotal moment (Barrell, 2013). This development 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-Art 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, 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 process 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 study 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) uses headsets to create immersive digital games, training, and education environments. 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, and is applied in engineering, healthcare, and education with devices like HoloLens (Sala, 2021).

In conclusion, the chapter illustrates and discusses the key milestones, thresholds, and shifts 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, especially in different reality environments (Table 2.1)

Table 2.1 Concise Overview of Key Milestones, Thresholds, and Shifts of ADSE.

Year	**Event**	**Deta**
30-20 BC	The First Written Resource: Vitruvius	Vitruvius's "The Ten Books on Architecture" highlights the balance between theory ("ratiocinatio") and practice ("fabrica") in architectural education.
1671	The First Academic Architectural Institution: The Académie d'Architecture	Founded in France, it was the first institution dedicated to comprehensive architectural study. It was dissolved in 1793 but its legacy continued with the École des Beaux-Arts.
1819	The First Design Studio: The École des Beaux-Arts	Established in Paris, introduced the design studio concept which became fundamental to formal architectural education worldwide.
1919	The First Design Studio-Centered Education: Bauhaus	Bauhaus emphasized creativity, imagination, and individual expression over technical constraints, integrating theory and practice in an interdisciplinary environment.
1920-2019	Evolution of Design Studio Education & Space	Shifted from apprenticeship to studio-based environments. Weekly studio sessions became standard, fostering dialogue and semi-structured learning approaches.
1950s-Ongoing	Evolution of Design Studio Education & Space with Technology	Began integrating computers and IT into architectural education, leading to CAD and digital tools becoming essential. Flexible physical infrastructures supported adaptable teaching methods.
2019-2021	Design Studio Education during COVID-	Transitioned to remote learning using platforms like Zoom, Google Hangouts, and Microsoft Teams. Highlighted the need for vibrant online learning communities and the challenges of replicating studio environments online.
Ongoing	Evolution of Design Studio Education & Space with Emerging Technologies	Integration of XR (Extended Reality) including VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality). Emphasizes the balance between virtual simulations and tangible, hands-on experiences in design education.

2.1 Evolution of Design Studio Education “Firsts”

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. On the other hand, 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 the realm of 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 the 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 early times.

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 École des Beaux-Arts and continues to influence architecture schools worldwide to this day (Griffin, 2019).

Lectures at this academy covered 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.

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.

The First Design Studio-Centered Education: Bauhaus, 1919

Salama and Wilkinson (2007) 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. Balamir (1985) 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. 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 (Hacihasanoglu, 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.

2.2 Design Studio Education and Thresholds Beyond the Early 20th Century

Evolution of Design Studio Education & Space, 1920-2019

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 et al., 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. 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. Stevens (1998) emphasizes that the design studio is widely recognized as the most distinctive and critical activity within the architectural curriculum. 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 these studios is through dialogue, which facilitates the development, elaboration, and enrichment of understanding (Crowther, 2013; Biggs, 1999; 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.

Evolution of Design Studio Education & Space with Technology, 1950-Ongoing

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, 2002; Reffat, 2007). Reffat (2007) 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.

Crowther (2013) 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 (2007) notes that it has become common practice for students to use notebook computers in many architecture schools. 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.

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.

Design Studio Education Timeless

Crowther (2013) argues that the term "studio" is widely employed in the realm of 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 (1991) 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.

The design studio is the foundation of architectural education, demanding a comprehensive understanding 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 is undeniable; it serves as a space where students are shaped into creative and problem-solving individuals. However, to ensure that every student has a comprehensive, fair, and productive learning environment, it is essential to continuously evaluate and update the educational approaches within the studio atmosphere.

Evolution of Design Studio Education and Space with Technology During Covid-19 Pandemic, 2019-2021

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., 2022). Still, this shift presented various challenges, including 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 (2021) observed how the pandemic disrupted the conventional approach to architectural design courses, presenting opportunities for examination and reform.
- Asfour et al. (2023) 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.
- Grover and Wright (2023) 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.
- Alnusairat et al.'s (2021) 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.

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.

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 A., 2021)

During the COVID-19 pandemic, architectural education transitioned from conventional in-person teaching to online distance learning, presenting significant challenges. While this shift has opened opportunities for evaluation and reform, it has also exposed several issues, such as digital literacy difficulties, infrastructure limitations, and the complexities of replicating the interactive studio environment online. Research conducted during the pandemic highlighted the importance of fostering vibrant online learning communities and peer-to-peer support in digital education. A thoughtful and meticulous approach to transitioning studio-based teaching to an online format is essential. Exploring alternative pedagogical strategies is crucial for effectively delivering remote architectural education. Blended learning methods hold promise but should enhance rather than replace conventional teaching approaches, particularly in the early stages of design study programs. Addressing resource disparities and fostering global connections among architectural institutions can improve 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.

Evolution of Design Studio Education and 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 advent 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, particularly 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 T., 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 R., 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 (Chucwukelu 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 (AR), in design education (Darwish, Kamel, & Assem, 2023). Evaluated by these improvements and unexpected shifts, extended Reality (XR), characterized by Gownder et al. (2016), 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 (2021) 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) provides comprehensive definitions of virtual reality, augmented reality, and mixed reality, highlighting their distinctive characteristics, practical applications, and utilization within education (Table 2.2).

Table 2.2 VR, AR, MR Features, Devices, and Applications in Education Fields (Sala, 2021).

	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 virtual environment; 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 and hold 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 (2021) 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.

As technological advancements continue, virtual reality (VR) holds great potential, particularly in education (Estes et al., 2021). In online settings, virtual worlds provide three-dimensional 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 historical and travel 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. As we navigate the everchanging 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.

Conclusion and Discussion

This chapter explores the evolution of design studio education with its firsts and thresholds. It presents crucial shifts in design studio education, instruction methods, and space, such as transitioning from the master's place/space to the contemporary design studio space within architecture schools (Table 2.3).

Table 2.3 Evolution of Design Studio Education Instruction and 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 2.1).

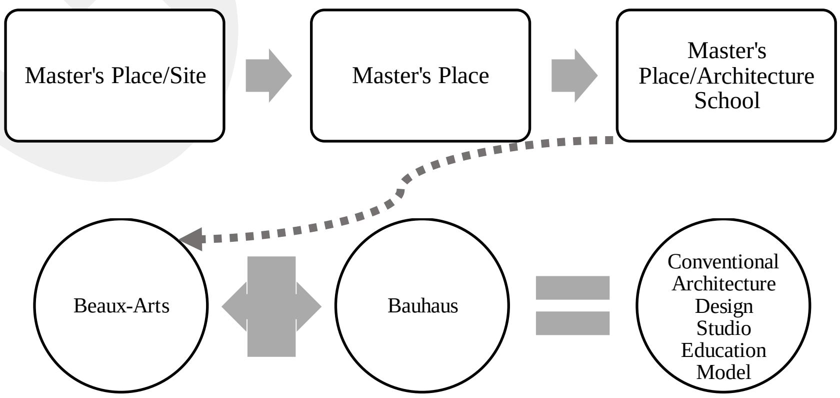


Figure 2.1 Conventional architectural design studio education model formation diagram.

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 2.4)

Table 2.4 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 2.2).

Figure 2.2 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. Conventional 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 conventional 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 2.3), integrating or shifting XR; 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 conventional methods. Each technology can offer different opportunities to the design studio's education and environment.

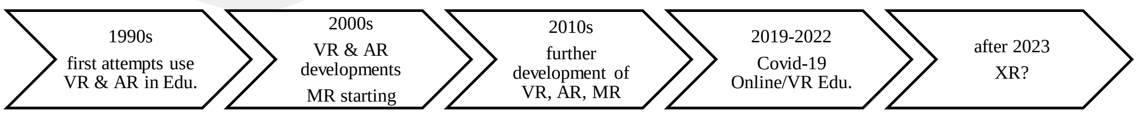


Figure 2.3 VR, AR, and MR technologies developments and their educational usage process

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. Scholars can observe virtual components overlaid on their physical models or studio spaces using AR eyewear or mobile gadgets. 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 concurrently engage with physical and digital entities. 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.

In conclusion, considering the historical evolution alongside contemporary developments and transformations, it can be argued that design studio education is on the brink of a significant shift (Figure 2.4).

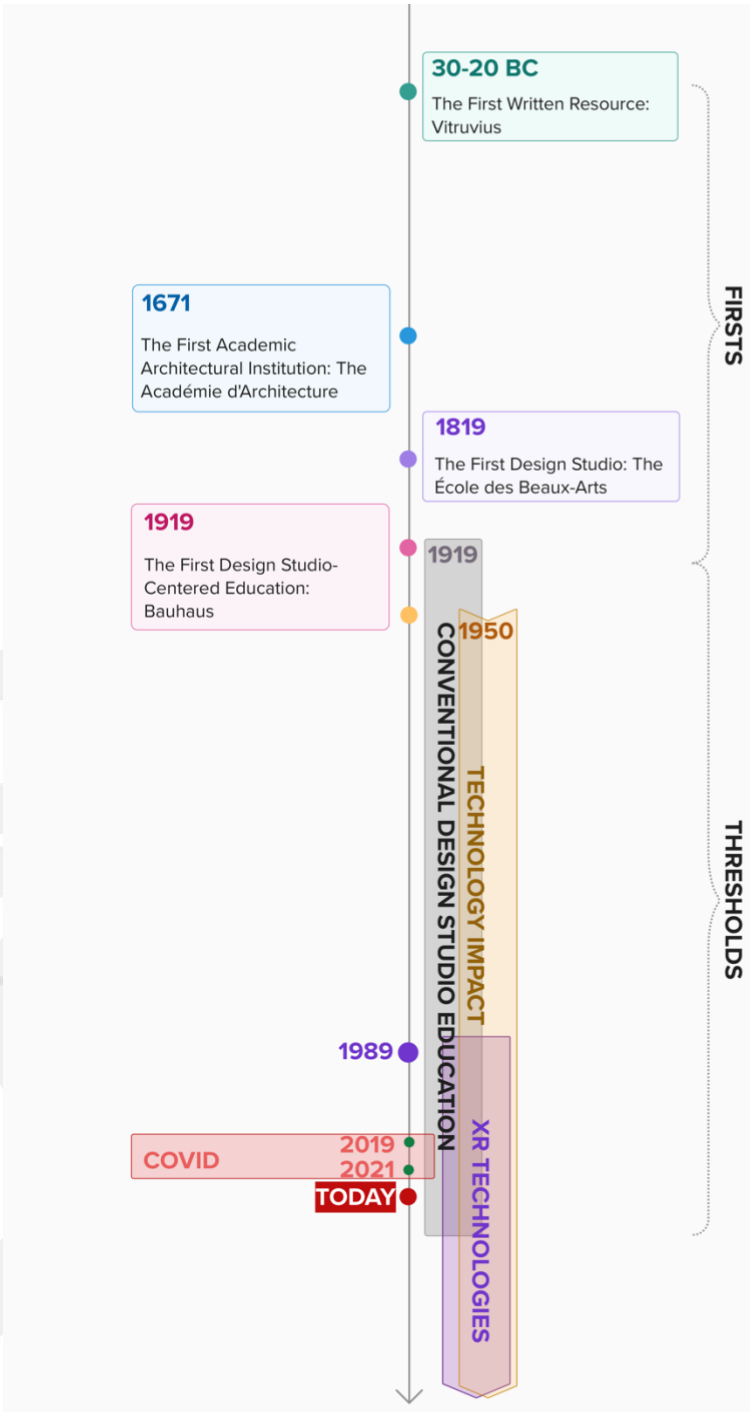


Figure 2.4 Timeline of Architectural Design Education with its 'Firsts' and 'Thresholds'.

Emerging technologies have the potential to greatly reduce reliance on conventional physical design studios. With the necessary equipment and internet connectivity, students can access design studio education from virtually any location, enhancing accessibility and allowing for a wider range of participants. These advancements make education more inclusive and open up new possibilities for how design studio education is delivered and experienced.

Chapter 3

Architectural Design Education and Extended Reality Technologies

Extended Reality (XR) technologies encompass a spectrum of immersive technologies that merge the physical and virtual worlds. XR includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), each offering distinct experiences. XR technologies fundamentally rely on computer-generated content, real-time interactions, and the seamless integration of digital and physical elements (Azuma et al., 1997). In VR, users are entirely immersed in a computer-generated environment, often facilitated by headsets, controllers, and sensors, resulting in a high degree of presence and immersion (Slater and Wilbur, 1997). AR, on the other hand, overlays digital information in the real world, providing contextual information and enhancing the user's understanding of their surroundings (Azuma et al., 2001). MR combines elements of both VR and AR, enabling users to interact with digital objects while still being aware of their physical environment (Milgram and Kishino, 1994) (Figure 3.1).

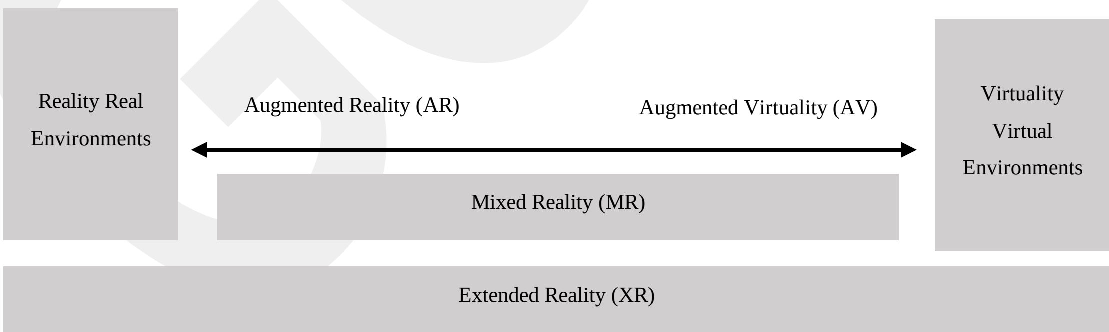


Figure 3.1 Reality-Virtuality continuum by Milgram and Kishono, with the concept of Extended reality by Horvathova et al. (Darwish M., Kamel S., Assem A. 2023: Horvathova, Vostinar, Mitter, 2020).

Understanding the fundamentals and components of XR technologies is essential for exploring their applications and implications in various domains, including architectural design studio education.

Estes et al. (2021) state that the goal of education is for students to develop more than just knowledge and skills; it is for them to become interested in and involved in the learning process, work well with peers, think critically, solve problems to deal with unforeseen problems and develop a lifelong learning mindset that allows them to apply their knowledge, skills, and digital literacy to real-life situations.

Technology development has touched every aspect of human effort, including higher education. Technology's influence has permeated the core of higher education teaching and learning, helping to provide and improve the student experience and encouraging productive engagements. Technology has cleverly been used in higher education teaching and learning in the modern world to support a variety of elements, components, and processes like teaching, learning, curriculum design, and evaluation. The impact is enormous when connected to learning objectives and standards (Alhazmi, 2021).

Chucwukelu et al. (2021) state that distance learning programs typically use intelligent technology in education. Despite its apparent advantages, distance learning presents difficulties for teaching and learning. First, because there is no reciprocal face-to-face contact between online students and their teachers, it is more difficult for them to get to know one another and develop dynamic, collaborative relationships like in a conventional classroom. Benefits: Encourages student enrollment, effective and prompt feedback, and communication between students and teachers through omnipresent technologies. Issues include expense, the lack of a classroom environment, privacy concerns, users' unease with using their personal information online, and AI in human-centered activities.

With the advent of big data, machine learning, and artificial intelligence, the world is revolutionizing education in the knowledge set through several significant technological developments (Ara and Das, 2021). Within their overall structure, universities are organized into various distinct types of units. Of course, schools, divisions, and programs exist to facilitate teaching and learning organization. These courses center on accepting students, ensuring they receive the proper training, evaluating their performance, and completing a degree-worthy course of study. While the core operational processes stay constant, the content of their activities may gradually change as new curriculum aspects are added, and some older ones are reduced in size or abolished. They must maintain stability so students obtain what was promised when they applied (Natriello, 2021).

Gownder et al. (2016) define extended reality (XR) as all mixed real-and-virtual worlds and human-machine interactions produced by computer technology and wearables. It comprises Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and the realms in between.

Idrees et al. (2022) mention that depending on their research shows prospects for innovation in teaching and learning, as well as the emergence of Extended Reality (XR) technology in various sectors, which calls for additional investigation. However, more research is needed to determine teachers' resources to experiment with, create, and use XR technologies.

Sala (2021) asks and responds whether virtual, augmented, and mixed reality are suitable teaching tools for classroom settings. The answer may be favorable, but it's crucial to remember that not all educational settings benefit from VAM (virtual, augmented, mixed) realities.

As technology tools, features, and capabilities continue to improve, it has been clear in the past that VR may be used to support such development. This trend shows great promise for the future. While analyzing VR's evolution and quick development today, it's crucial to consider where VR started, the developments that have made it more accessible to a larger audience, and the prospects for integration and adoption in education (Estes et al., 2021).

Sala (2021) summarizes the history of VR, AR, and MR use in education as;

- 1989-1999 - This decade is marked by the first attempts to use VR and AR technology with students of different ages in educational paths.
- 2000-2010 – This decade was marked by the rapid development of electronic components, making it possible to reduce the use of VR and AR technologies. This has enabled applications in various educational fields. During this time, MR began to become famous. This is undoubtedly the newest and least known of the three technologies.
- 2011-2020 - Further development of VR, AR, and MR. These technologies are also expanding their fields of application, making them more interactive and promoting participation in teaching and learning.

Online settings, known as virtual worlds, allow users to engage with three-dimensional representations of real-world objects or phonemes. The virtual environment could represent a fantasy virtual world or look like the real world (with genuine rules, real-time actions, interactions, and communications). Recently, internet-based 3DVW has flourished and shows promise for significantly impacting how people connect and communicate. Application of 3DVW (three-dimensional virtual worlds) in higher education categories is virtual lecturing (%49), discussion (%32), field trips (%14), simulation (%28), and gaming (%11) in literature. (Ghanbarzadeh and Ghapanchi, 2021).

Ghanbarzadeh and Ghapanchi (2021) express -that according to the research, most studies in the literature have produced the same findings, and real-world lectures have produced superior results. Seventeen major categories have been established for the virtual environments used for educational purposes. The most typical 3D virtual environments used by educational institutions are virtual classrooms, virtual laboratories, virtual meeting spaces, simulated locations, and replicas of well-known locations. Some well-informed guidelines exist for utilizing these Technologies to achieve specific learning outcomes. They can use technology as a resource to produce innovative, creative, and efficient teaching and learning methods.

Organizing virtual excursions inside virtual settings for educational purposes utilizing 3DVWs is feasible. It is a led and narrated tour of a 3DVW (three-dimensional virtual world), a virtual simulation of a real place or an imagined site that may be chosen by educators and set up so that students can visit, follow directions, and conduct an investigation just by navigating around the virtual environment. Students can become familiar with various historical and travel spots worldwide by visiting virtual locations (Ghanbarzadeh and Ghapanchi, 2021).

Several issues with the technology need to be resolved before VR can be used as an educational tool in architecture and other technical fields. For instance, the limited resolution of low-cost viewing devices led to unrealistic projects, it took time to sustain high frame rates on personal computers, and hardware and software devices were expensive (Sala, 2021).

Whether these technologies can deliver comparable learning outcomes for trainees attending real-world classes is one of the crucial questions about the usability of 3DVW in higher education. According to students' and educators' feedback, the research shows that 3DVWs can significantly improve teaching and learning outcomes, positively impacting students' achievement and offering more options for delivering education compared to real-world and in-person classes. This is supported by the literature review that the researchers conducted (Ghanbarzadeh and Ghapanchi, 2021).

In the subsections of this chapter, a systematic literature review methodology was applied. Searches were conducted using Science Direct, Scopus, and Web of Science databases, covering the years 2019 to 2024, with keywords relevant to the research questions. These databases were chosen due to their comprehensive coverage of high-quality, peer-reviewed research in the fields of science and technology. The period from 2019 to 2024 was selected to capture the most recent developments and emerging trends in VR, AR, MR, and XR technologies. This review aims to identify patterns, recurring themes, and gaps in the existing literature. The analysis provided insights into the contributions, challenges, and development potentials of VR, AR, MR, and XR technologies in architectural design studios.

The reviews followed PRISMA (2020) (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines to ensure a transparent and comprehensive approach to the literature review process. By adhering to PRISMA (2020) guidelines, the review process included meticulous data extraction, quality assessment, and synthesis of findings to draw meaningful conclusions. PRISMA (2020) guidelines involve several key steps: defining clear research questions, establishing inclusion and exclusion criteria, conducting a thorough search of relevant databases, selecting studies based on predefined criteria, extracting and synthesizing data, and assessing the quality of the included studies. This systematic approach enhances the reliability and validity of the review findings.

3.1 Virtual Reality Technology and Architectural Design Education

Virtual Reality (VR) is an immersive technology that creates a simulated, computer-generated environment where users can interact with and often become a part of the digital world. This technology aims to provide a multisensory experience that tricks the human senses into perceiving a virtual environment as real. VR technology offers a high degree of immersion, surrounding users with a wholly digital environment that typically occludes the physical world. VR systems are interactive, allowing users to engage with the virtual environment through gestures, movements, or controllers. They often engage multiple senses, including sight and sound, and may include tactile feedback through haptic devices. This systems track users' movements in physical space, enabling them to explore the virtual environment from different angles (Oculus Web Page, 2023)

VR's ability to bridge the gap between theoretical knowledge and practical experience makes it a valuable tool in architectural design studio education, offering students a more immersive and engaging learning environment.

Architectural design studio education is the linchpin of pedagogical evolution within the architectural domain. Rooted in the historical evolution from conventional mentorship to its contemporary status, this educational model epitomizes a complex interplay of components. Its adaptability to emerging technological paradigms, particularly "Virtual Reality" (VR) technologies, presents a significant trajectory deserving of detailed investigation. This systematic literature review explores the integration and implications of VR technologies within architectural design studio education, offering comprehensive insights into its multifaceted impact. The primary research questions focus on how virtual reality (VR) technology is employed in architectural design studio education, its effects on learning experiences, and its intensity in the studies of the architecture field with keywords relevant to the research questions. Selected studies specifically explored experiential learning in architectural design studios, particularly utilizing VR technology.

Eligibility Criteria

The eligibility requirements for this research acknowledge the refined progression of architectural design studio education by incorporating VR technology. The study's objective is to investigate the future path of design education. The research maintains rigorous selection criteria to offer significant stakeholder perspectives and contribute to the ongoing scholarly discussion in the field (Table 3.1).

Inclusion Criteria

The eligibility criteria outline the parameters for selecting studies examining the integration of virtual reality (VR) technology in architectural design studio education. These criteria emphasize investigations exploring the application and impact of VR within this educational context. The selection process prioritizes papers addressing VR and architectural design studio education, especially those investigating using VR technologies for experiential learning in architectural design studios.

Table 3.1 Systematic Literature Review Results in Science Direct, Scopus, WoS Databases.

Database	Query Formula/Terms	Type	Research Area	Results
Science Direct	Find articles with these terms: virtual reality technology in architectural design studio education	Review article, research article	Engineering, Social Sciences, Art & Humanities	176
Scopus	ALL (virtual AND reality AND technology AND in AND architectural AND design AND education) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "ARTS") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "ENGI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACTKEYWORD , "Virtual Reality") OR LIMIT-TO (EXACTKEYWORD , "Architectural Design"))	Article	Engineering, Social Sciences, Art and Humanities, Multidisciplinary	899
Web of Science	Virtual reality technology in architectural design education (All Fields) and 2024 or 2023 or 2022 or 2021 or 2020 or 2019 (Publication Years) and Article or Review Article (Document Types) and Architecture or Education Educational or Art or Research or Art or Multidisciplinary Sciences or Social Sciences Interdisciplinary (Web of Science Categories) and Article or Early Access or Review Article (Document Types)	Review article, article	-	19
TOTAL				1094

Exclusion Criteria

The exclusion criteria for this systematic literature review involve filtering out studies not focused on VR technology, those unrelated to higher education or architecture, and any off-topic or divergent works. Only papers directly aligned with the review's focus on VR technology in architectural design studio education were included. Non-English studies and duplicate publications were also excluded to ensure methodological rigor and the selection of relevant sources. Following a clear-defined procedure, the review process involved identifying, screening, and including articles, resulting in the exclusion of numerous papers based on specific criteria: duplicates (n = 8), scholarly works unrelated to virtual reality (n = 32), content not related to higher education (n = 264), material unfocused on architecture (n = 190), studies conducted outside architectural design education (n = 570), and that were inaccessible (n = 8) (Figure 3.2).

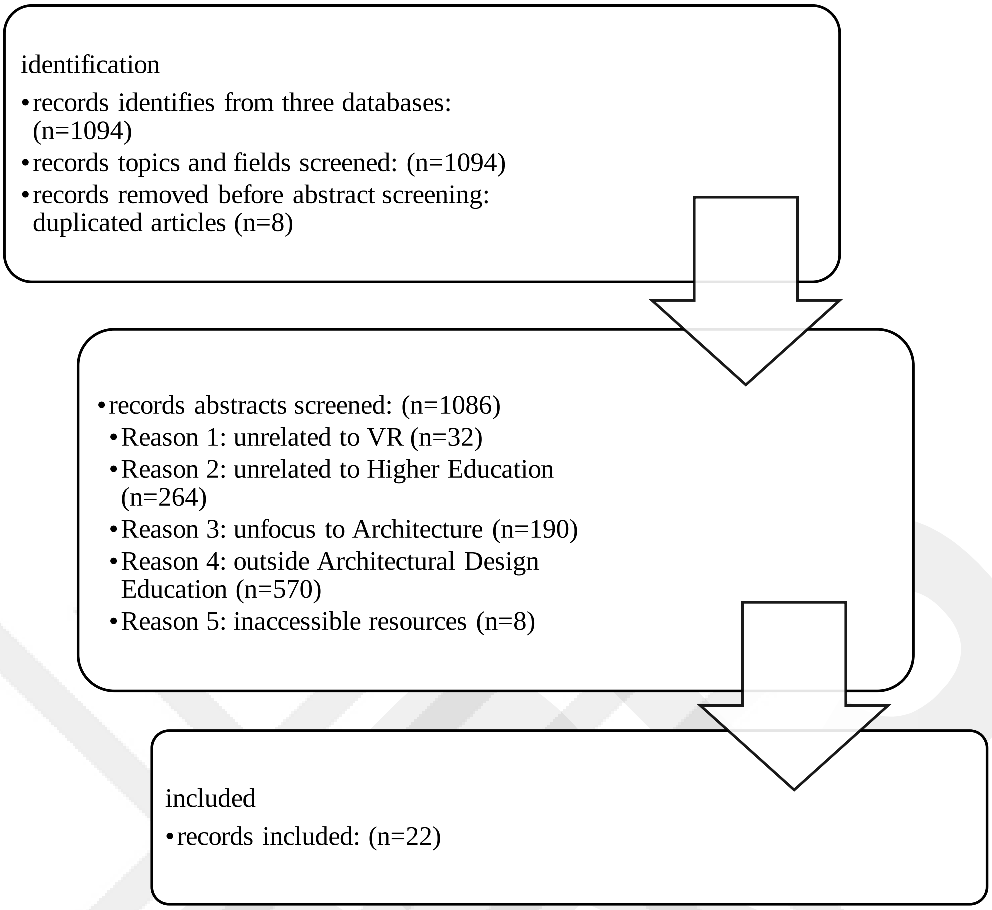


Figure 3.2 Modified Prisma Flow Diagram (VR and ADSE).

This systematic process identified twenty-two papers most relevant to the study's aim. These papers were evaluated based on their aims and conclusions to explore the utilization of VR technology in architectural design studio education (Table 3.2).

Table 3.2 Most Related Papers as a Result of Systematic Literature Review (VR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	VR Relation	Conclusions
1	An investigation of architectural design process in physical medium and VR	Doma O.O. & Sener S.M. 2022	examining how virtual reality (VR) impacts the process of architectural design.	create innovative experiments involving 14 participants, combining tangible lego bricks with VR through dreamscape bricks VR.	explores the differences between VR and physical design processes by utilizing VR tools for constructing architectural models.	VR offers unique possibilities in design, enabling modifications in user size and enhancing engagement in various activities.
2	Introducing Immersive Virtual Reality in the Initial Phases of the Design Process	Gomez-Tone H. C. et al. 2022	exploring the impact of IVR in early architectural design stages on enhancing students' design skills.	employing diverse research methods, including mixed methodology, participatory observations, and surveys.	uses immersive virtual reality (IVR) to boost spatial perception and experimentation in the early phases of architectural design.	IVR elevates students' design skills through enriched spatial perception and iterative design enhancements, leading to improved achievement.
3	Implementing Affordance-Based Design Review Method Using Virtual Reality in Architectural Design Studio	Agirachman F. A. et al. 2022	investigating the impact of utilizing virtual reality for affordance-based design evaluations in architectural education.	implementing VRDR in an ongoing architectural design studio course as a case study.	utilizing VR to assess design results through affordance-based review, examining both conventional and VR techniques.	VRDR completely changes the design review process by enabling students to recognize and tackle both positive and negative aspects of their designs, ultimelevating the overall quality of the design.
4	The virtual body in a design exercise: a conceptual framework for embodied cognition	Mejia-Puig L. & Chandrasekera T. 2023	exploring the impact of virtual body conditions in VR on creativity and spatial abilities.	creating a framework that combines physical presence and mental processing to evaluate virtual body states.	explores how virtual body representations in VR affect thinking and creativity in design.	embodied virtual bodies in VR have the potential to enhance presence and spatial skills, but they might also heighten cognitive load, impacting cognition and design results.
5	An empirical study on immersive technology in synchronous hybrid learning in design education	Kee T. et al. 2023	exploring VR’s impact on hybrid design education through pedagogical effectiveness measurement.	a blend of quantitative and qualitative methods for collecting data.	explores how VR can elevate experiential learning in hybrid education, contrasting it with conventional learning methods.	VR elevates learning through immersive experiences, boosting student engagement, motivation, and comprehension of design concepts.

Table 3.2 (Continued) Most Related Papers as a Result of Systematic Literature Review (VR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	VR Relation	Conclusions
6	The Impact of Immersion through Virtual Reality in the Learning Experiences of Art and Design Students	Guerra-Tamez C. R. 2023	analyzing the influence of immersive VR on the educational journey of art and design students.	literature review, conceptual model development, hypothesis testing	explores the impact of VR immersion on motivation, curiosity, cognitive advantages, and critical thinking in art and design instruction.	engaging in VR enhances learning through increased motivation, cognitive advantages, and reflective thought, despite potential usability issues.
7	Virtual Reality as a Design Tool to Achieve Abstract Concepts of Spatial Experience: A Case Study of Design Studio Teaching	Ibrahim, M. & El Shakhs, A. 2023	demonstrating the effectiveness of VR in design education for improved understanding and outcomes.	exploring the essence of student project evaluations through a detailed analysis of workflow descriptions in a qualitative study.	uses VR technology to precisely capture real-world dimensions and elicit personal feelings via immersive spatial encounters.	utilizing VR technology empowered students to refine and elevate their design ideas through immersive feedback, resulting in concrete improvements and better grasp of complex concepts.
8	Integrating Simulation into Design: An Experiment in Pedagogical Environments	Lee S. et al. 2022	ınvestigating the influence of intelligent design support and simulation-based design in architectural learning.	exploring protocols through interviews and simulation-based design tasks.	uses ABM simulation tool to observe behaviors in design processes and evaluate differences with conventional design methods.	simulation tools enabled dynamic exploration and continuous design enhancements, unveiling the advantages and constraints of simulation in educational design.
9	Using systems thinking to understand the evolving role of technology in the design process	Huber A.M. et al. 2022	exploring the ramifications of systems thinking on the function of technology in the growth of design.	exploring existing knowledge in literature to construct an innovative conceptual framework.	explores how different technologies, such as VR, influence the design process and are incorporated into design education.	technology, such as VR, greatly influences contemporary design methods by boosting design potential and creating fresh avenues for creativity.
10	Design studio practice in the context of architectural education: a narrative literature review	Hettithanthri U. & Hansen P. 2022	analyzing the creative methods and techniques used in design firms.	narrative literature review.	explores the integration of VR and digital technologies in conventional and innovative design studio settings.	conventional design studio practices need to evolve to include more context-generated design studios, leveraging digital tools like VR for enhanced creativity and learning.

Table 3.2 (Continued) Most Related Papers as a Result of Systematic Literature Review (VR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	VR Relation	Conclusions
11	Understanding virtual design behaviors: A large-scale analysis of the design process in Virtual Reality	Wang, P. et al. 2024	exploring the design behaviors and strategies used by designers in virtual reality settings.	large-scale analysis, data collection from VR design sessions.	examining how virtual reality impacts design choices and processes by studying design behaviors in VR settings.	VR enables distinctive design approaches and actions, elevating innovation and productivity in designing.
12	Effect of virtual reality on perceptions of usability, suitability, satisfaction, and self-efficacy among architecture and design university students	Alsswey A. et al. 2024	exploring how students' perceptions of usability, suitability, satisfaction, and self-efficacy are influenced by the use of the VR gravity sketch tool.	Al-Zaytoonah University of Jordan contributed 161 students to a pre-post-test control group assessment.	examines how VR affects usability, suitability, satisfaction, and self-efficacy in architecture and design education.	the incorporation of VR technology into educational curriculum enhances students' views on usability, suitability, satisfaction, and self-efficacy.
13	The impact of virtual technology on students' creativity: A meta-analysis	Wang, Y. et al. 2024	exploring how virtual technology influences students' creativity.	analyzing multiple studies on virtual technology's impact on creativity.	explores how virtual technology, such as VR, impacts students' creative abilities.	virtual technology, such as VR, boosts students' creativity through immersive and interactive environments for exploration.
14	Digital technologies in architecture, engineering, and construction	Brozovsky J. et al. 2024	analyzing how digital technologies have influenced architecture, engineering, and construction.	analyzing the diverse range of digital technologies and their integration in architecture, engineering, and construction.	explores the merging of different digital tools, such as VR, in AEC for enhanced design and construction methods.	VR, along with other digital technologies, revolutionizes design and construction processes through increased precision, productivity, and teamwork.
15	Impact of extended reality on architectural education and the design process	Kharvari F. & Kaiser L. E. 2024	analyzing the implications of extended reality (XR) on architectural education and design processes.	a mix of methodologies including surveys, interviews, and case studies.	explores the impact of XR technologies on the learning and creative aspects of architecture.	XR technologies revolutionize architecture by offering immersive experiences and interactive learning, despite facing obstacles like cost and accessibility.
16	Architectural education challenges and opportunities in a post-pandemic digital age	Saleh M. M. et al. 2023	exploring the challenges and potential in architectural education during the digital era after the pandemic.	exploring through literature, surveys, and interviews.	embarks on the use of digital tools like VR to tackle obstacles and maximize potential in architectural education after the pandemic.	digital technologies such as VR present great potential for improving architectural education through interactive and immersive learning settings.

Table 3.2 (Continued) Most Related Papers as a Result of Systematic Literature Review (VR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	VR Relation	Conclusions
17	The contribution of digital tools to architectural design studio: A case study	Ceylan S. et al. 2024	exploring how digital tools enhance architectural design studios.	investigating students' viewpoints on digital tools through a case study and questionnaire.	explores how digital tools, such as VR, can elevate the design studio experience.	VR and other digital tools are pivotal in contemporary design studios, boosting communication, teamwork, and innovation, particularly in the shift to online learning.
18	Extended reality for enhancing spatial ability in architecture design education	Darwish M. et al. 2023	investigating how XR can improve spatial skills in architectural design education.	analyzing spatial ability through pre- and post-tests in an experimental study.	explores the application of XR technologies like VR and AR to enhance architectural students' spatial skills.	XR technologies boost architectural students' spatial skills by offering enhanced experiences that deepen comprehension of spatial concepts.
19	Virtual reality space in architectural design education: Learning effect of scale feeling	Hou N. et al. 2024	investigating how experiencing scale in VR impacts architectural design education.	comparing the effectiveness of conventional learning methods with VR in an experimental study.	explores how VR influences students' perception of size and spatial connections in architecture.	VR enhances students' grasp of scale and spatial connections through an engaging and interactive educational journey.
20	New terroirs: Lessons from Hong Kong for seamless digital and physical interactions	Kay-Jones S. & Janvier L. 2022	exploring the fusion of digital and physical interactions within urban design in Hong Kong.	exploring through case studies, observing, and conducting interviews.	explores blending VR and digital tools to enhance connections between digital and physical spaces in urban planning.	VR and digital technologies elevate urban planning through blending virtual and physical realms, optimizing functionality and user engagement.
21	Exploring immersive learning technology as learning tools in experiential learning for architecture design education	Ummihusna A. & Zauril M. 2022	examining the capability of immersive learning technology to improve experiential learning in the domain of architecture.	creating and applying architectural spatial experience simulation (ASES) for surveys.	utilizes VR in architectural spatial experience simulation to enhance students' spatial comprehension and experiential education.	VR revolutionizes experiential learning through enhancing students' spatial comprehension and involvement, offering a compelling substitute for conventional field trips.
22	Immersive virtual reality in experiential learning for architecture design education: An action research	Ummihusna A. et al. 2024	analyzing how immersive virtual reality impacts experiential learning and students' learning strategies.	exploring through action research by implementing architectural spatial experience simulation (ASES), utilizing surveys and reflective memos.	employs VR to simulate real-life encounters in field trips, enriching students' immersive spatial exploration and learning.	virtual reality enhances students' spatial perception and promotes a more profound learning method, proving to be a beneficial asset in architectural education.

The systematic review identified and analyzed 22 studies focused on integrating Virtual Reality (VR) technology in architectural design studio education. These studies provide comprehensive insights into how VR has enhanced learning experiences and pedagogical methods in architecture.

One of the most significant findings across the reviewed studies is the enhancement of students' spatial understanding and visualization capabilities through the use of VR. For instance, the study by Gomez-Tone et al. (2022) demonstrated that immersive virtual reality (IVR) significantly improved students' spatial perception and design competencies during the initial phases of architectural design. Similarly, Hou et al. (2024) found that VR environments helped students better grasp scale and spatial relationships, which are crucial in architectural design education.

Alsswey et al. (2024) explored how VR affects usability, suitability, satisfaction, and self-efficacy among architecture and design university students. Their findings indicated that incorporating VR technology into the educational curriculum enhances students' perceptions of these aspects, making them more confident and satisfied with their design processes.

Several studies have highlighted VR's positive impact on student engagement and motivation. Guerra-Tamez (2023) noted that immersion in VR environments increased students' motivation and curiosity, enhancing their overall learning experience. Kee et al. (2023) also reported that VR as a pedagogical tool in hybrid learning environments led to higher levels of student engagement and understanding of design concepts than conventional methods. The adoption of VR has facilitated more innovative and iterative design processes. Doma and Sener (2022) investigated how VR design processes compare with conventional physical design methods using LEGO bricks and found that VR allowed for greater flexibility and creativity in design iterations. Ibrahim and El Shakhs (2023) demonstrated that VR technology enabled students to understand better and realize abstract spatial concepts, enhancing their design proposals based on VR feedback.

Several studies have focused on VR's role in experiential learning and its applications in real-world scenarios. Ummihusna and Zairul (2022) examined the capability of immersive learning technology to improve experiential learning in architecture. They found that VR significantly enhances spatial comprehension and provides a compelling substitute for conventional field trips. This immersive experience allows students to engage with their designs in a more tangible and meaningful way, promoting a deeper understanding of architectural concepts.

While the benefits of VR in architectural education are clear, several studies also pointed out challenges and usability issues. Mejia-Puig and Chandrasekera (2023) highlighted that while embodied virtual bodies in VR can increase spatial skills, they can also increase cognitive load, potentially affecting overall cognition and design outcomes. Additionally, Guerra-Tamez (2023) mentioned usability challenges, such as technical difficulties and the need for ergonomic improvements in VR equipment.

The systematic review also underscored the broader implications of VR technology for architectural education. Huber et al. (2020) discussed how VR, as part of broader digital transformation, is reshaping the design education landscape by providing new opportunities for innovation and enhancing design capabilities. Saleh et al. (2023) explored the post-pandemic digital age, identifying VR as a crucial tool in addressing educational challenges and leveraging new opportunities for more flexible and interactive learning environments.

In summary, integrating VR technology in architectural design education offers substantial benefits, including enhanced spatial understanding, increased student engagement, and more innovative design processes. However, implementing VR technology presents challenges related to usability and cognitive load. The systematic review suggests that VR is valuable in modern architectural education, promoting creativity, efficiency, and a deeper understanding of architectural concepts. This review contributes to the ongoing discourse on digital innovation in education, highlighting VR's transformative potential in shaping the future of architectural education (Figure 3.3).

Figure 3.3 Conclusion of VR Technology and ADSE Review.

3.2 Augmented Reality Technology and Architectural Design Education

Augmented Reality (AR) is a technology that blends digital elements with the real world to create an enhanced, mixed-reality environment. Unlike virtual reality, which immerses users in a wholly digital world, AR supplements the physical environment by overlaying computer-generated content onto real-world objects or scenes. AR's ability to merge the physical and digital worlds makes it a valuable tool in architectural education, offering students interactive and context-rich learning experiences.

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

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

The primary research questions focus on how Augmented Reality (AR) experiences are employed in architectural design studio education, their effects on learning experiences, and their intensity in the studies of the architecture field. It aims to provide an evidence-based understanding of the impact of digital technology, particularly AR, on experiential learning in architectural design education and practice.

The review identified 1155 articles on augmented reality (AR) technologies in architectural design education keywords. After applying inclusion and exclusion criteria, ten articles remained for analysis.

Table 3.3 Systematic Literature Review Results in Science Direct, Scopus, WoS Databases.

Database	Query Formula/Terms	Document Type	Research Area	Results
Science Direct	Find articles with these terms: Augmented Reality Technologies in Architectural Design Education	Review article, research article	Engineering, Social Sciences,	1098
Scopus	TITLE-ABS-KEY (augmented AND reality AND technologies AND in AND architectural AND design AND education) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))	Review article	-	20
Web of Science	Augmented Reality Technologies in Architectural Design Education (All Fields) and Article or Review Article (Document Types) and English (Languages) and Review Article or Article (Document Types) and 2020 or 2021 or 2022 or 2023 or 20 24 (Publication Years) and Review Article or Article (Document Types)	Review article	-	37
TOTAL				1155

Eligibility Criteria

The eligibility requirements for this research acknowledge the refined progression of architectural design studio education with the incorporation of AR technology; the study's objective is to investigate the future path of design education.

Inclusion Criteria

The selection process prioritizes papers addressing AR and architectural design studio education, especially those investigating the use of AR technologies for experiential learning in architectural design studios.

Exclusion Criteria

The exclusion criteria for this systematic literature review involve filtering out studies not focused on AR technologies, those unrelated to higher education or architecture, and any off-topic or divergent works. Only papers directly aligned with the review's focus on AR technologies in architectural design studio education were included.

Non-English studies and duplicate publications were also excluded to ensure methodological rigor and the selection of relevant sources. Following a well-defined procedure, the review process involved identifying, screening, and including articles, resulting in the exclusion of numerous papers based on specific criteria: duplicates (n=7), scholarly works unrelated to augmented reality (n=125), content not related to higher education (n=9), material not focused on architecture (n=968), studies conducted outside architectural design education (n=35), and those not aligning with the review's objectives (n=0), as well as one unreachable source (Figure 3.4)

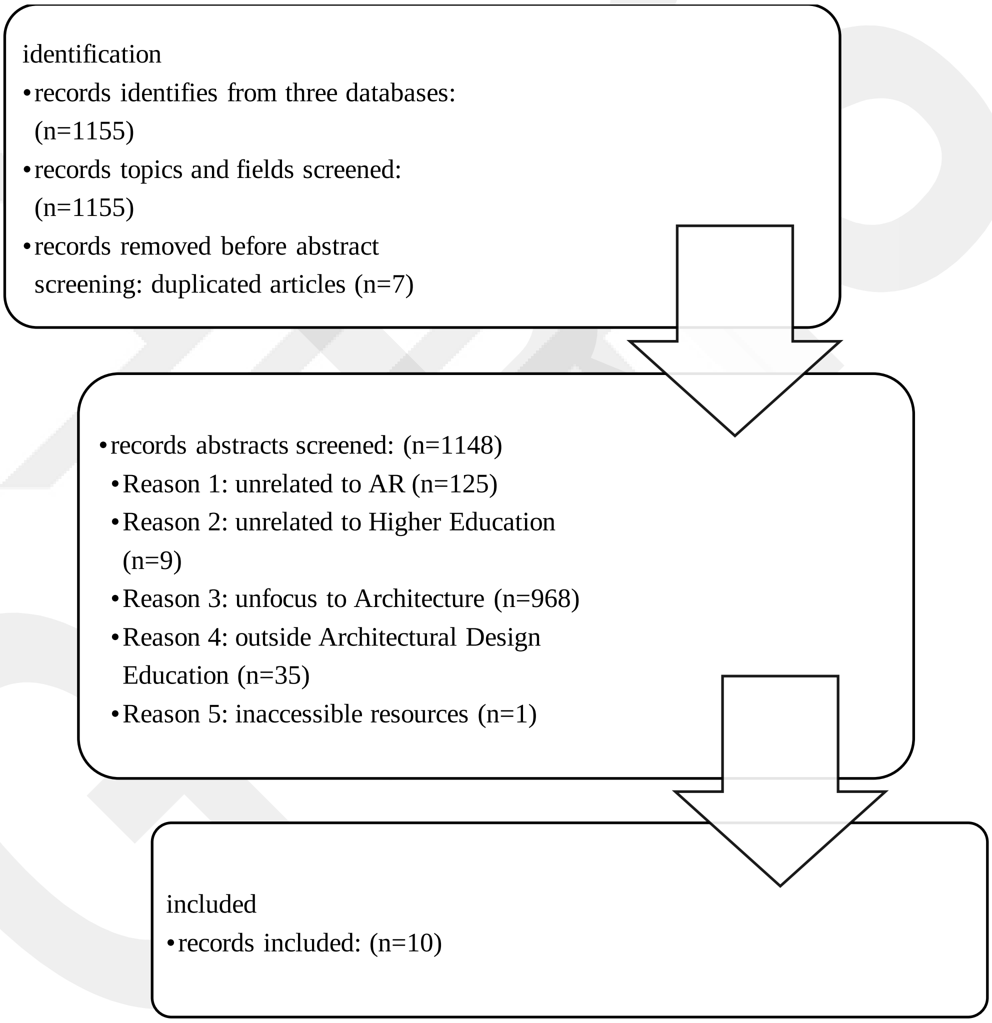


Figure 3.4 Modified Prisma Flow Diagram (AR and ADSE).

This systematic process identified ten papers as most relevant to the study's aim. These papers were evaluated based on their aims and conclusions to explore the utilization of AR technology in architectural design studio education (Table 3.4).

Table 3.4 Most Related Papers as a Result of Systematic Literature Review (AR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	Conclusion
1	Extended reality for enhancing spatial ability in architecture design education.	Darwish et al. 2023	explore the influence of extended reality technology on students' spatial cognitive skills and analyze its association with their academic performance.	a general spatial ability test was administered at baseline and after the project's completion. The utilization of XR technology was integrated into the initial design studio for an experimental investigation.	the utilization of XR technology led to a notable enhancement in the students' spatial ability scores. the main objection to the study focused on the missing control group.
2	Trends and Research Issues of Augmented Reality Studies in Architectural and Civil Engineering Education	Diao et al. 2019	examine trends in augmented reality (ar) and research challenges within the realm of education in architectural and civil engineering.	examination of AR development tools, system classifications, and educational applications. Use of visual inertial odometry (VIO) for real-time localization monitoring.	Augmented Reality (AR) is used in diverse educational methods and domain-specific learning, with cooperation vital for integrating AR research into education.
3	Augmented reality experience in an architectural design studio.	Alp et al. 2023	examine students' inclination towards novel representation methods in architectural design and the relationship between AR technologies and their design proficiency.	emerging technologies as AR and software tools Rhinoceros and Grasshopper are used across various fields. Survey methodology is for exploring the potential of augmented reality in architectural education.	a strong correlation was observed between gender and the utilization of computer programs in designs; a robust correlation was observed between gender and the utilization of computer programs in designs.
4	Extended reality in AEC	Trindade et al. 2023	to provide an overview of extended reality application in the architecture, engineering, and construction (AEC) industry.	a systematic review conducted. The formulation and implementation of precise taxonomies were employed to categorize the research findings.	the conclusions center on XR applications within the fields of architecture, engineering, and construction.
5	A Worldwide Journey through Distance Education—From the Post Office to VR, AR and MR, and Education during the COVID-19 Pandemic.	Pregowska et al. 2021	to offer a comprehensive examination of the evolution of distance education.	an exploration of the historical advancement of distance education in secondary and higher education	distance education has evolved in secondary and higher education. The COVID-19 accelerated profound changes in educational experience.
6	Framework for the Use of Extended Reality Modalities in AEC Education	Spitzer et al. 2022	a decision-making framework is put forth for the selection of XR technologies in the field of education.	systematic literature review of 983 papers from Scopus digital library. The development and utilization of particular taxonomies for the purpose of consolidating research.	a framework for decision-making aids educators in the AEC industry in the selection of suitable XR technologies.

Table 3.4 (Continued) Most Related Papers as a Result of Systematic Literature Review (AR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	Conclusion
7	Integrating augmented reality technologies into architectural education: application to the course of landscape design at Port Said University	Hussein 2023	investigate the advantages of incorporating AR technology in landscape design education to enhance students' understanding of the intricacies of the landscape design process.	an experiment with fourth-year architecture students at Port Said University involved using a mobile-based AR application, performing exercises, and completing a feedback questionnaire on AR integration.	the integration of Augmented Reality (AR) positively impacts landscape design education, enriching the learning experience and leading to a deeper understanding and acquisition of knowledge for students.
8	The Application of Extended Reality Technology in Architectural Design Education: A Review	Jingwen et al. 2023	investigate the utilization of XR technology in construction education over the past 5 years, assess its advantages and disadvantages in architectural education, and identify potential avenues for further research on extended reality technology in the educational sector.	conduct content analysis to synthesize and evaluate research outcomes by categorizing and scrutinizing documents according to specific classification standards.	XR technology enriches architectural education by enhancing instructor efficacy and fostering increased student engagement. It is likely that XR technology will eventually supplant conventional pedagogical approaches in educational settings.
9	Comparison of Building Design Assessment Behaviors of Novices in Augmented- and Virtual-Reality Environments	Hartless et al. 2020	investigate the adoption of Augmented Reality (AR) and Virtual Reality (VR) in advancing tacit knowledge.	engage Augmented Reality (AR) and Virtual Reality (VR) in empirical observations to boost tacit knowledge acquisition, employing pre- and post-questionnaires, statistical assessments, and video documentation for data gathering.	utilizing AR and VR technologies facilitates wheelchair-accessible tasks, promotes group interaction, and provides immersive, real-life educational experiences for students.
10	Impact of extended reality on architectural education and the design process	Kharvari et al. 2022	XR technologies optimize the various stages of the design process and enhance educational achievements. Applicable for the field of professional architectural design, it also facilitates the participation of end-users throughout the process.	The Modified PICO strategy and framework analysis were employed for the systematic review. Conceptual studies and theoretical proposals lacking AR/VR technology information were omitted.	XR technologies like VR, AR, and MR enhance learning and student performance in architectural education through immersive experiences. A structured framework is needed for effective curriculum integration.

Among the included studies, several key themes emerged regarding the integration and impact of Augmented Reality (AR) technologies in architectural design education. Most studies highlighted AR technologies' positive influence on various components of design studio education, particularly in fostering experiential learning opportunities. Through AR, students could engage in immersive experiences that facilitated a deeper understanding of architectural concepts and design principles. For instance, Darwish et al. (2023) and Hartless et al. (2020) demonstrated that utilizing XR technology, including AR, significantly improved students' spatial cognitive skills and tacit knowledge acquisition. These findings suggest that AR technologies can potentially enhance students' spatial perception and design proficiency, making abstract concepts more tangible and understandable.

AR's ability to augment reality with digital information allows students to visualize and interact with complex architectural designs more effectively. Studies by Darwish et al. (2023) and Hartless et al. (2020) found that students using AR technologies showed marked improvements in their spatial abilities and cognitive skills, particularly in tasks requiring a deep understanding of spatial relationships and three-dimensional structures. The immersive nature of AR helps bridge the gap between theoretical knowledge and practical application, enhancing cognitive skills that are crucial in architectural design.

Spitzer et al. (2022) proposed decision-making frameworks for selecting appropriate XR technologies in architectural education. These frameworks aim to guide educators in integrating AR technologies effectively into curriculum design and instructional practices. By providing a structured approach, these frameworks help ensure that the integration of AR technologies is aligned with educational objectives and learning outcomes, thereby maximizing their impact.

Alp et al. (2023) observed a strong correlation between gender and the utilization of computer programs in architectural design, highlighting potential disparities in technological proficiency among students. This finding suggests that while AR technologies offer significant educational benefits, gender disparities must be addressed to ensure equitable access and proficiency in using these technologies. Tailored training programs and inclusive teaching strategies could help mitigate these disparities.

While the studies underscored the promise of integrating AR technologies in architectural design education, they also acknowledged the need for further exploration to address challenges and optimize these technologies' full potential.

The review emphasized the importance of comprehensive evaluation in fully understanding AR technologies' impact on learning outcomes. Studies such as those by Darwish et al. (2023) and Hartless et al. (2020) provided valuable insights but also highlighted the need for long-term studies to assess the sustainability and scalability of AR integration in educational settings. Addressing these factors is crucial for developing effective and sustainable AR-enhanced educational practices.

The literature synthesis revealed a growing interest in integrating AR technologies into architectural design education. Studies demonstrated positive impacts on learning outcomes, spatial abilities, and engagement. However, future research endeavors should address existing gaps, such as gender disparities in technological proficiency and the need for comprehensive frameworks for AR integration. Ensuring sustainable implementation and ongoing evaluation will be key to leveraging the full potential of AR technologies in educational contexts (Figure 3.5).

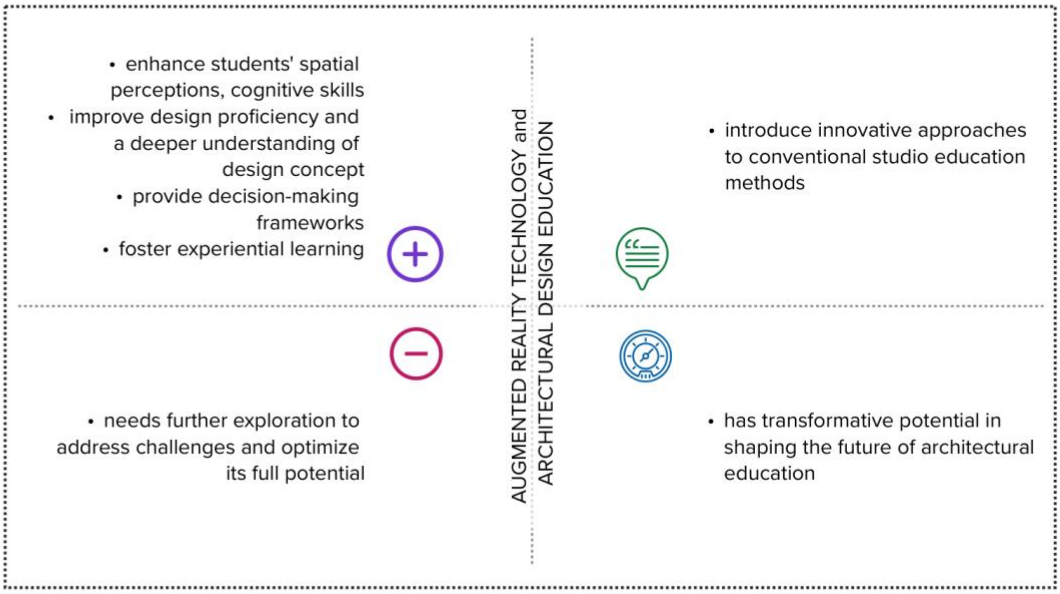


Figure 3.5 Conclusion of AR Technology and ADSE Review.

3.3 Mixed Reality Technology and Architectural Design Education

Mixed Reality (MR) is a technology that merges elements of the physical and virtual worlds, creating a seamless and interactive environment where physical and digital objects coexist and interact in real-time (Milgram P. & Kishino F., 1994). In MR, users can engage with computer-generated objects or information while being aware of and interacting with their physical surroundings. This technology offers a spectrum of experiences ranging from the real to the virtual world, with varying degrees of digital content integration (Azuma, 1997).

Mixed Reality (MR) technology combines aspects of the physical and virtual worlds to create immersive and interactive experiences. MR hardware components, including headsets, controllers, and sensors, enable this technology. Immersion and presence are fundamental to MR, providing users with a sense of engagement and coexistence in real and virtual environments. In architectural design studio education, MR offers valuable applications for design exploration, collaboration, concept visualization, and site analysis, enriching the learning experience for students (Tang et al., 2020).

Mixed reality (MR) technologies, such as Microsoft HoloLens, part of the broader extended reality (XR) spectrum, allow students to examine three-dimensional architectural setups within their real-world context. This capability is vital for grasping complex spatial relationships and the dimensions of architectural elements, significantly improving spatial awareness and design skills (Milgram & Kishino, 1994). MR permits real-time interaction with design elements, enabling students to alter and refine architectural models digitally. This active engagement deepens understanding of the implications of design decisions and supports a more iterative, flexible design process (Milman, 2018). Additionally, MR facilitates collaborative design projects by allowing multiple students to interact with a communal virtual prototype, irrespective of their location. This approach promotes teamwork, enhances negotiation skills, and seamlessly integrates various design elements (Parveau & Adda, 2018).

Technology implementation is critical in determining the curricula and instructional methods in the rapidly evolving field of architectural design education. The systematic literature review examines the integration, impacts, and future potentials of mixed reality

(MR) technologies in architectural design education. The review aims to accomplish three primary objectives: evaluate the utilization of MR technologies in architectural design instruction, investigate their impact on learning and results, and pinpoint obstacles to their integration into educational environments. The significance of this critique rests in its ability to guide upcoming research paths and educational methods. The primary research questions focus on how mixed reality (MR) technology is employed in architectural design studio education, its effects on learning experiences, and its intensity in the studies of the architecture field.

Eligibility Criteria

The eligibility requirements for this research acknowledge the refined progression of architectural design studio education with the incorporation of MR technology; the study's objective is to investigate the future path of design education. The keywords MR technology and architectural design education are used for review (Table 3.5).

Table 3.5 Systematic Literature Review Results in Science Direct, Scopus, WoS Databases.

Database	Query Formula/Terms	Document Type	Research Area	Results
Science Direct	Find articles with these terms: mixed reality technology in architectural design studio education	Review article, research article	Engineering, Social Sciences	102
Scopus	ALL (mixed AND reality AND technology AND in AND architectural AND design AND education) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "ARTS")) AND (LIMIT-TO (EXACTKEYWORD, "Architectural Design") OR LIMIT-TO (EXACTKEYWORD, "Mixed Reality"))	Article	Engineering, Social Sciences, Art and Humanities	216
Web of Science	Mixed reality technology in architectural design education (All Fields) and 2019 or 2020 or 2021 or 2022 or 2023 or 2024 (Final Publication Year) and Review Article **or** Article (Document Types)	Review article, article	-	15
TOTAL				333

Inclusion Criteria

The eligibility criteria outline the parameters for selecting studies examining the integration of mixed reality (MR) technology in architectural design studio education. These criteria emphasize investigations exploring the application and effects of MR within this educational context. The selection process prioritizes papers addressing MR and architectural design studio education, especially those investigating the use of MR technologies for experiential learning in architectural design studios.

Exclusion Criteria

The exclusion criteria for this systematic literature review involve filtering out studies not focused on MR technology, those unrelated to higher education or architecture, and any off-topic or divergent works. Only papers directly aligned with the review's focus on MR technology in architectural design studio education were included. Non-English studies and duplicate publications were also excluded to ensure methodological rigor and the selection of relevant sources. Following a clear-defined procedure, the review process involved identifying, screening, and including articles, resulting in the exclusion of numerous papers based on specific criteria: duplicates (n = 4), scholarly works unrelated to MR (n = 60), content not related to higher education (n = 141), material not focused on architecture (n = 19), studies conducted outside architectural design education (n = 96), and those not inaccessible (n = 1) (Table 3.6).

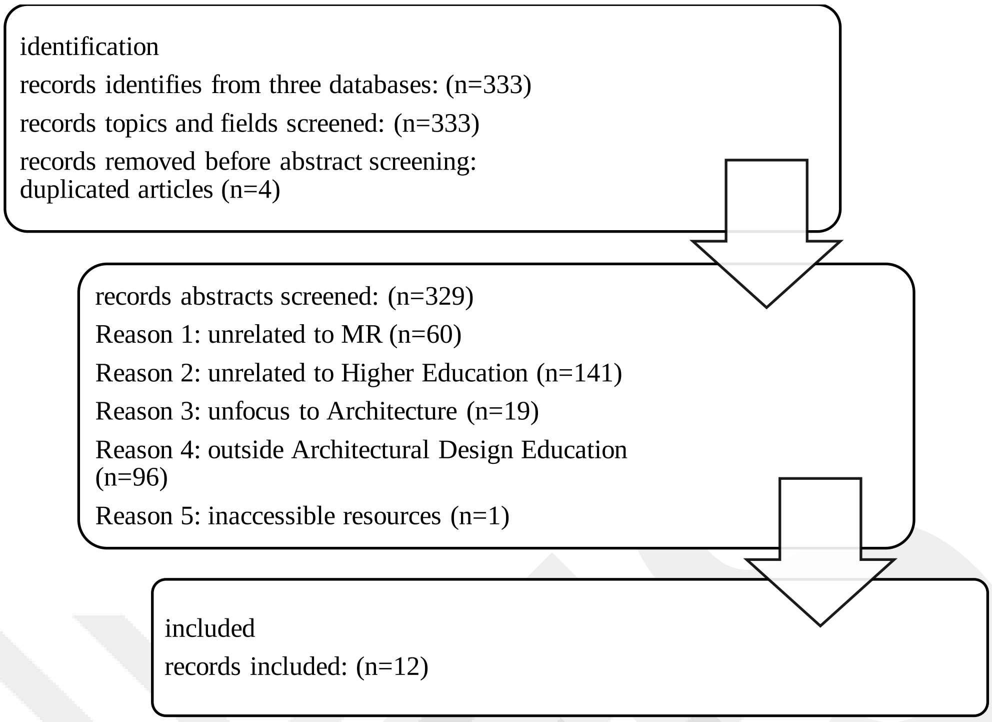


Figure 3.6 Modified Prisma Flow Diagram (MR and ADSE).

This systematic process identified twelve papers most relevant to the study's aim. These papers were evaluated based on their aims and conclusions to explore the utilization of MR technology in architectural design studio education.

Table 3.6 Most Related Papers as a Result of Systematic Literature Review (MR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	MR Relation	Conclusions
1	Architectural education challenges and opportunities in a post-pandemic digital age.	Saleh M. M. et al. 2023	exploring challenges in architectural education and proposing digital-era strategies that leverage pandemic-driven opportunities.	examining literature how the pandemic affects architectural education to find issues and chances for post-pandemic models.	exploring how MR enhance architectural education by improving design, collaboration, and learning environments.	highlights the pandemic's effects on architectural education and suggests a model emphasizing networking, exploration, and adaptability.
2	Collaborative Educational Environments Incorporating MR Techs: A Systematic Mapping Study	Ali A. A. et al. 2019	to analyze literature on using MR in education to find trends, challenges, and research gaps.	systematic mapping out the evolution and identifies gaps in mixed reality technologies in education.	MR technologies analyzed for their use in collaborative learning environments like virtual classrooms & simulation-based learning.	discovers growing interest in MR technologies in education, highlighting research gaps technical issues.
3	Exploring the Potential of MR in Enhancing Student Learning Experience and Academic Performance	Almufarreh A. 2023	to study how MR boosts student learning & academic performance and to examine the effect of MR on learning and student satisfaction.	a numerical method was used with a survey based on the Likert and data analysis and structural equation modeling.	MR is used for immersive learning to engage students. MR technologies blend digital and physical environments for studying.	applying MR significantly improves students' learning experiences, leading to increased satisfaction and academic success.
4	XR for enhancing spatial ability in architecture design education	Darwish M. et al. 2023	investigates how early use of XR techs affects spatial skills in architectural education, aiming to boost spatial imagination.	uses control and experimental groups to compare the effectiveness of XR versus conventional methods.	examines how XR fosters engaging learning, reduces cognitive load, and enhances spatial understanding.	XR boosts spatial skills in architecture students, despite challenges in adapting to new technologies.
5	Framework for the Use of Extended Reality Modalities in AEC Education	Spitzer B. O. et al. 2022	seeks a framework to help AEC educators select XR technologies, considering budget, scalability, space, and educational outcomes.	provides a detailed review of XR modalities in AEC education, proposing a framework to select XR tools based on educational goals.	evaluates MR, VR, and AR within the extended reality spectrum, assessing their impact on visualization, engagement, and interactive learning in AEC education.	emphasizes the transformative impact of XR on AEC education, advocating for integration to improve student engagement and outcomes.
6	HoloDesigner (HD): A mixed reality tool for on-site design	Dan Y. et al. 2021	offers MR & the HD tool enhance on-site design via real-time visualization & manipulation of 3D models in actual settings.	involves using the HD tool with Microsoft HoloLens for real-time MR integration, tested to evaluate design based on user experiences.	HD uses MR to integrate virtual 3D models with real settings, allowing designers to modify designs on-site through spatial mapping and gesture control.	HD enhances on-site design, improving accuracy in architectural and urban planning decisions.

Table 3.6 (Continued) Most Related Papers as a Result of Systematic Literature Review (MR and ADSE).

No	Topic	Author(s)	Aim	Method(/ology)	MR Relation	Conclusions
7	Impact of extended reality on architectural education	Kharvari F. & Kaiser L. E. 2022	to evaluate XR technologies in ADSE, XR impact on student performance & offers curriculum proposal.	reviews XR technologies in architectural education from 2015-2020 using a modified PICO strategy.	highlights (MR) in architectural education, enhancing student engagement and learning.	finds XR benefits architectural education by improving the design process, enhancing learning outcomes, and involving end-users.
8	Interactive Parametric Design and Robotic Fabrication within Mixed Reality Environment	Buyruk Y. & Cagdas G. 2022	to test integrating parametric design & robotic fabrication in MR to enhance design & fabrication via real-time interaction.	creates a digital twin in mixed reality using parametric modeling and robotic fabrication with visual updates.	uses MR to enhance parametric design and robotic fabrication with real-time adjustments and multi-user support in a shared virtual space.	combining parametric design and robotic fabrication in mixed reality boosts design flexibility, efficiency, and speed, enhancing human-robot collaboration and user experience.
9	Proposing a Novel MR Framework for Basic Design (BD) and Its Hybrid Evaluation Using Linkography and Interviews	Cindioglu H. C. et al. 2021	exploring the impact of MR on design thinking skills among novice designers in BD education, enhancing their capacity to create and assess design options.	uses linkography and interviews to analyze design moves and investigate how students benefit from MR technology.	uses the DesignMR framework to enhance design education with MR, improving creativity and real-time feedback by integrating physical and digital elements.	shows that DesignMR improves creativity, productivity, and idea exploration for novice designers. MR is beneficial in BD education, allowing students to consider solutions and be involved in the design process.
10	The Contribution of Digital Tools to Architectural Design Studio: A Case Study	S. Ceylan et al. 2024	investigating the impact of digital tools on architectural design studios during the pandemic-induced shift to online education.	a case study using a questionnaire for students to collect opinions on digital tools in the studio process.	MR is used in architectural education to improve visualization and design features.	MR in architectural education improves visualization and design, enabling real-time changes and collaborative feedback, learning, understanding, and creativity.
11	The Application of Extended Reality Technology in Architectural Design Education: A Review	Wang J. et al. 2023	analyzes XR technology's applications in ADSE over to provides a theoretical framework for future use.	uses content analysis and a literature review to assess XR technology in architectural education.	MR enhances architectural education, improving understanding and offering real-time feedback and collaboration.	XR technologies enhance architectural education by promoting active learning, encouraging reflection and communication, and potentially replacing conventional teaching.
12	Design Assessment in Virtual and Mixed Reality Environments: Comparison of Novices and Experts	Wu W. & J. Hartless J. 2020	investigates how VR and MR can connect inexperienced and skilled designers in construction.	uses VR and MR simulations, collecting data through think-aloud protocols, surveys, and recordings.	VR and MR technologies created authentic virtual learning experiences, direct interaction with design tasks.	VR and MR narrow the gap between novices and experts, enabling novices to perform expert tasks through immersive learning experiences.

This systematic literature review examined twelve critical articles selected from three hundred thirty-three, focusing on integrating Mixed Reality (MR) technologies in architectural design education. The articles reviewed consistently underline the transformative potential of MR in revolutionizing conventional architectural educational methods. MR technologies, notably VR and AR, offer an immersive, hands-on experience that significantly enhances learning outcomes, as evidenced in studies such as Saleh et al. (2023). These technologies support conventional educational content and introduce innovative pedagogical approaches that foster deeper interaction and involvement. The result is a more dynamic learning environment where students can actively experiment with and comprehend intricate design principles, paving the way for a new era in architectural education.

Several research studies, such as the one by Darwish and colleagues (2023), have stressed the effectiveness of MR in improving essential skills required for architectural design, such as spatial awareness and visualization capabilities. The immersive nature of MR enables a more profound understanding of spatial relationships, which is a critical element of architectural training. Engaging with MR technologies allows students to dynamically see and interact with structures, enhancing spatial cognition and problem-solving skills.

The incorporation of MR has dramatically increased student involvement and satisfaction levels. Almufarreh's (2023) research shows that integrating MR improved academic achievement and enriched educational experiences. MR technologies enhance learning by making it more engaging and exciting, grabbing and holding students' attention, thus improving overall academic performance and satisfaction. This shift towards interactive learning is crucial to staying abreast of digital progress in educational approaches.

Despite the beneficial effects, implementing MR in architectural education faces obstacles regarding technology integration, costs, and alignment with the curriculum, as seen in research such as Dan et al., (2021). Implementing MR technologies mandates significant investments in hardware, software, and training for educators. Furthermore, integrating MR into current curricula involves systematically restructuring course frameworks and learning objectives to incorporate new technologies effectively.

The systematic mapping study by A. Ali et al. (2019) highlighted research gaps, especially in augmented virtuality and technical integration challenges. Further investigation is necessary to explore the lasting effects of MR technologies and develop more robust frameworks for their integration. Subsequent research efforts should focus on overcoming these challenges and improving the scalability and accessibility of MR technologies in architectural education.

In conclusion, this academic review emphasizes the potential benefits of MR technologies in transforming architectural design education by improving experiential learning, boosting student engagement, and imparting essential skills. However, it underscores the need for further research to effectively tackle the associated challenges of these technologies and fully leverage their benefits in educational settings.

Integrating Mixed Reality (MR) technologies in architectural design education has significantly improved spatial understanding, interactive learning, and design skills. MR technologies provide immersive environments where students can engage more extensively with educational content, making conventional learning methods more engaging and dynamic. These environments offer deeper insights through the instant visualization and manipulation of architectural concepts.

However, integrating MR comes with challenges, such as high implementation costs and the need for specialized teacher training. Various studies highlight these challenges as global barriers in educational settings. Resistance to change within education systems and the necessity for curriculum modifications also hinder the adoption of these advanced technologies.

The impact of MR technologies in education is significant; they enhance student engagement and satisfaction, improve preparation for architectural careers, and align educational experiences with the industry's evolving demands. However, realizing the full potential of these technologies requires continuous research, strategic planning, and careful integration strategies.

Future research should focus on creating cost-effective alternatives, increasing the accessibility of MR technologies, and developing flexible structures that facilitate their integration into diverse educational environments. As MR technology advances, its impact on architectural education will grow, leading to more interactive and technology-infused learning spaces (Figure 3.7).

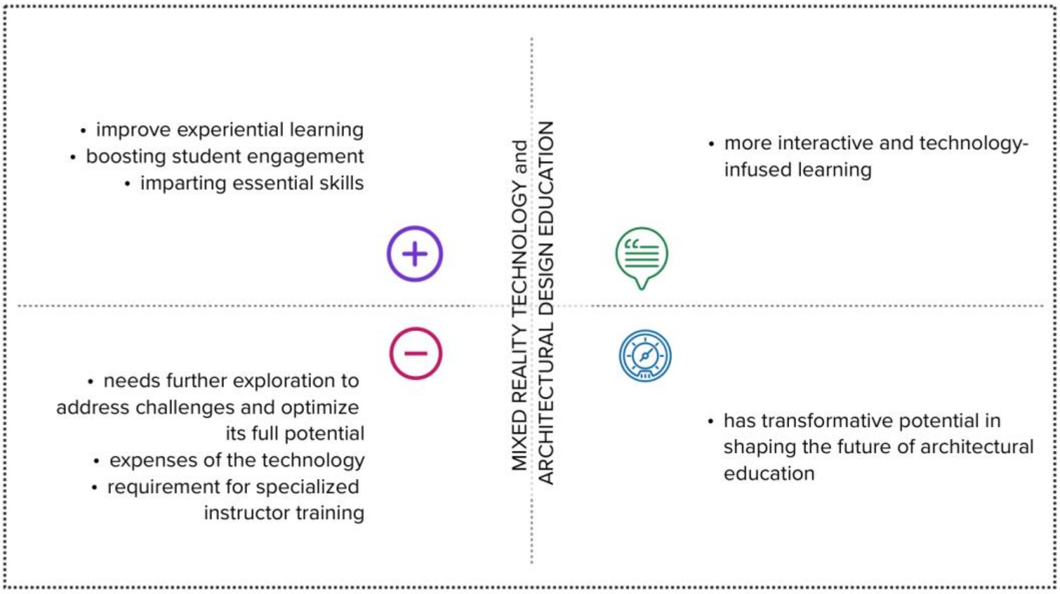


Figure 3.7 Conclusion of MR Technology and ADSE Review.

3.4 Extended Reality Technology and Architectural Design Education

Extended Reality (XR) technologies encompass a variety of immersive technologies that blend the physical and virtual worlds. XR includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), each providing unique experiences. These technologies fundamentally depend on computer-generated content, real-time interactions, and the smooth integration of digital and physical elements (Azuma, 1997).

Gownder et al. (2016) describes extended reality (XR) as encompassing all combinations of real and virtual worlds and interactions between humans and machines facilitated by computer technology and wearable devices. XR includes Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR), along with the intermediate states between these technologies (Darwish et al. 2023; Gownder et al., 2016).

With its features, XR technologies promise to enhance architectural design education.

Employing a three-stage systematic review encompassing one hundred eighty-three abstracts rigorously scrutinizes the influence of extended reality technology on design studio education. By exemplifying exemplary applications of digital technology within design studios, it endeavors to shed light on associated benefits and challenges and contribute substantively to the evolving discourse on XR's role in architectural education.

In the context of this study, the primary research questions are, “how are extended reality experiences utilized in architectural design studio education, and what effects do they have on experiences? Keywords relevant to the research question were used to identify relevant literature.

Studies explored experiential learning in architectural design studios, particularly utilizing extended reality (XR) technologies, were selected for inclusion. The most frequently used digital technologies in these studies were identified, and those focusing on XR technologies, which offer various tools and environments, were prioritized.

The evolution of design studio education is an intricate interplay of diverse influences, refraining from unilateral outcomes. This review investigates the imminent trajectory of architectural design studio education, scrutinizing the intricate components inherent in exploring XR technology’s role within this domain. Emphasizing the consequential impact of these investigations, the research seeks to provide a comprehensive understanding of XR’s implications on architectural design studio education and culture. By synthesizing this information, it aims to furnish invaluable insights to stakeholders in the field, contributing significantly to the scholarly discourse and the progression of the discipline. This systematic exploration, encompassing literature from Science Direct, Scopus, and Web of Science, maintains rigorous criteria for inclusion and exclusion (Table 3.7).

Table 3.7 Systematic Literature Review Results in Science Direct, Scopus, WoS Database.

Database	Query Formula/Terms	Document Type	Research Area	Category	Results
Science Direct	Find articles with these terms: the impact of XR on architectural education	Review article, research article	Engineering, Computer Science, Decision Sciences, Social Sciences, Environmental Sciences, Psychology	Engineering, Environmental Science, Psychology	79
Scopus	(ALL (the AND impact AND of AND xr AND in AND architectural AND education) AND PUBYEAR > 2018 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "ENVI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))	Review article	-	Engineering or Computer Science or Social Sciences or Arts and Humanities or Psychology or Multidisciplinary or Environmental Science	85
Web of Science	Results for ((ALL=(the impact of XR on architectural education)) OR ALL=(XR technologies and architectural design education)) OR ALL=(extended reality and architectural education) and 2019 or 2020 or 2021 or 2022 or 2023 (Publication Years) and Article or Review Article (Document Types) and Engineering Civil or Construction Building Technology or Environmental Sciences or Architecture or Education Educational Research or Engineering Environmental or Environmental Studies or Archaeology or Engineering Multidisciplinary or Computer Science Interdisciplinary Applications or Psychology Multidisciplinary or Imaging Science Photographic Technology or Remote Sensing (Web of Science Categories)	Review article	Architecture	Engineering Civil or Construction Building Technology or Environmental Sciences or Architecture or Education Educational Research or Engineering Environmental or Environmental Studies or Archaeology or Engineering Multidisciplinary or Computer Science Interdisciplinary Applications or Psychology Multidisciplinary or Imaging Science Photographic Technology or Remote Sensing	19
TOTAL					183

This systematic literature review considers architecture or design education studies, focusing on architectural design studio education, culture, and the integration of XR (Extended Reality) technology. The included investigations delve into the application, effects, or integration of XR Technologies within architectural design studio education. The selected researches explore the influence of XR experiences on various facets of architectural design studio culture, including tools, methodologies, interactions, and outcomes. Inclusion criteria were applied by focusing on XR and architectural design studio education on most related papers. Studies conducted during this specified period that specifically examined the use of experiential learning in architectural design studios, focusing on utilizing extended reality (XR) technologies, were selected for inclusion. The digital technologies most commonly employed in these studies were identified, and those that concentrated on XR technologies, which provide a range of tools and environments, were given precedence.

Literature not centered on XR technologies, studies unrelated to higher education, works not directly associated with architecture, and off-topic or divergent studies are excluded from this review. Specific papers selected for inclusion must align with the review's focus on XR technologies in architectural design studio education. Non-English language studies and duplicate publications are excluded. These criteria ensure a systematic literature review, emphasizing the selection of pertinent and rigorous sources essential for an extensive exploration of XR experiences in architectural design studio education.

The systematic literature review followed a well-defined procedure involving the distinct identification, screening, and inclusion stages. This methodological rigor facilitated the elimination of numerous articles based on specific criteria: duplicates (n=5), scholarly works deviating from the domain of extended reality (n=2), content unrelated to the of higher education (n=98), material not focused on the discipline of architecture (n=47), studies conducted outside the field (n=26), and particular research papers that did not align with the primary objectives of the review (n=2).

Duplicated papers: 5; Literature unrelated to XR technologies: 2; Literature unrelated to higher education: 98; Literature unrelated to architecture: 47; Off-field studies: 26; Specific papers irrelevant to the review's aim: 2 (Figure 3.8).

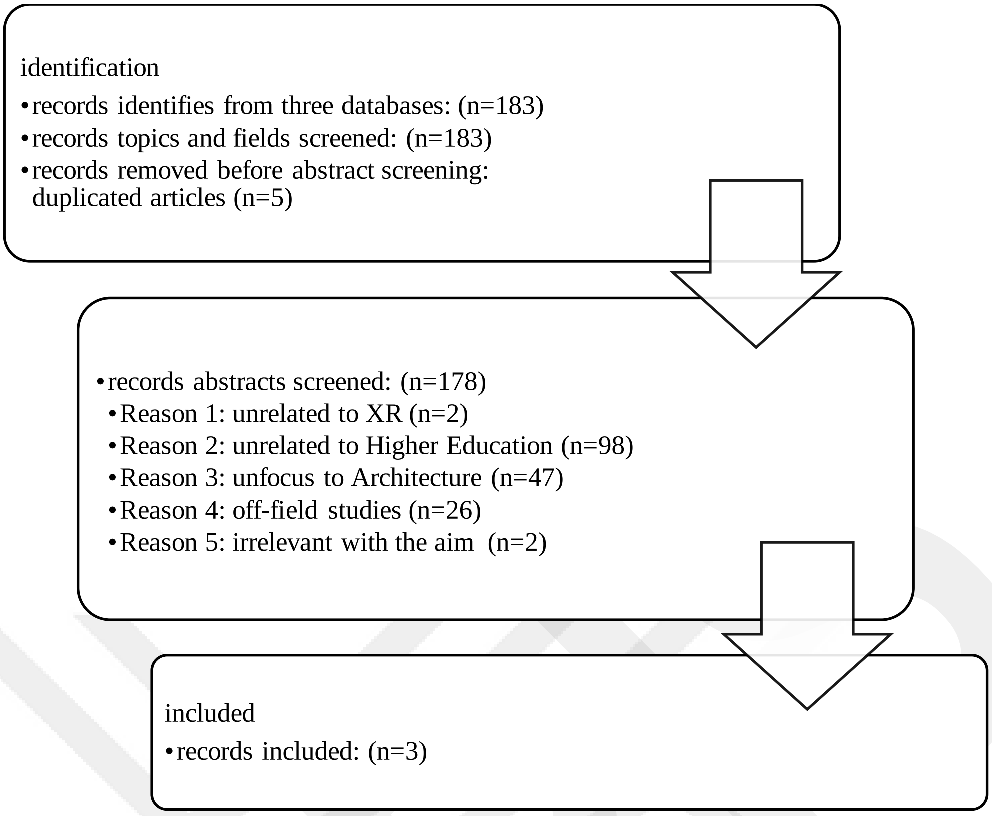


Figure 3.8 Modified Prisma Flow Diagram (XR and ADSE).

The systematic literature review identified three papers that are most related to this study's aim. To evaluate papers and their reviews and determine the utilization of XR technology in architectural design studio education, three main titles were created to evaluate them: method, aim, and conclusion (Table 3.8).

Paper 1: Darwish, M., Kamel, S., & Assem, A. (2023). Extended reality is used to enhance spatial ability in architecture design education. Ain Shams Engineering Journal, 14(6), 102104. https://doi.org/10.1016/j.asej.2022.102104.

Paper 2: Kharvari, F., & Kaiser, L. (2022). Impact of extended reality on architectural education and the design process. Automation in Construction, 141, 104393. https://doi.org/10.1016/j.autcon.2022.104393.

Paper 3: Spitzer, B. O., Ma, J. H., Erdogmus, E., Kreimer, B., Ryherd, E., & Diefes-Dux, H. (2022). Framework for the use of extended reality modalities in AEC Education. Buildings, 12, 2169.

Table 3.8 Included papers' main frame.

Paper	Method	Aim	Conclusion
1.Darwish et al., 2023	Review + Research	to explore the benefits and drawbacks of incorporating this technology in the initial stages of architectural design and assess its influence on student performance.	XR significantly improved students' spatial abilities and enriched architectural education by reducing cognitive burden.
2. Kharvari and Kaiser, 2022	Systematic Review	examine the effects of XR technologies on architectural education and investigate how XR technologies influence the design process.	XR tech helps architectural ed by enhancing learning and design.
3. Spitzer et al., 2022	Literature Review & Framework	proposed framework for AEC educators to integrate XR technologies into teaching methods	XR tech can enhance AEC education. A model suggests XR modalities to aid instructors. XR can boost perseverance and interest. The framework needs continuous updates due to rapid XR development.

Review papers and reviews of these three papers are examined using criteria such as focus, XR experience, XR tools, and conclusion and projection comments to investigate whether enhancing the components of conventional design studio education using XR technologies is possible and beneficial.

Paper 1: Extended Reality for Enhancing Spatial Ability in Architectural Design Education, Darwish et al., 2023

In Paper 1, experimental research carried out in this paper aims to conduct an empirical study in architectural education to assess the impact of XR technology on students' spatial ability. The study's findings reveal enhancement among those who utilized XR technology, unlike a control group that did not exhibit any alterations in their spatial competence scores. Furthermore, the paper comprehensively examines existing literature about using XR technologies in architectural design education, encompassing these previous applications' objectives, methodologies, conclusions, and limitations.

In the experimental research phase of this paper, the authors undertake a case study to investigate the influence of XR technology on spatial ability within the educational process of architectural design. To provide the VR experience, the authors utilized the VR-Oculus2 HMD and the Gravity Sketch Application, while for the AR experience, they utilized the iPad and the Augment Application. Second-year architecture students selected randomly from Ain Shams University were chosen to partake in an experiment to evaluate the impact of extended reality (XR) on spatial abilities. Participants engaged in augmented reality experiences as part of their design studio activities, utilizing either an iPad Pro or a smartphone. Spatial ability tests were administered before and after the XR-assisted sessions, with the overall scores as the dependent variable. To enhance the presentations and facilitate life-size virtual walkthroughs, the study utilized Immersive Virtual Environments (IVE). However, a notable limitation was identified in the XR system's incapability to simultaneously accommodate multiple users, thus affecting the collaborative nature of student interaction during the study.

In the review phase of this paper, the authors present a collection of previous papers that employed XR applications, offering insights into the aims, methodologies, findings, and significant limitations of each study under review. According to analysis, literature reviews examining virtual reality (VR), augmented reality (AR) technology, and mixed reality (MR) technology applications as XR technologies in the design process converge on the consensus that these technologies improve the understanding of dimensions, proportions, and design. Moreover, participants commonly perceive the utilization of VR and AR as a motivating, enjoyable, and thrilling experience. The authors assess five relevant studies that employ applications for integrating extended reality in architectural design education.

This study examined the paper and assessed the reviews of the papers in question from an alternative standpoint to assess the implementation of XR technology within the context of architectural design studio education. This evaluation was conducted within the framework of the study's focus point, which included considerations of XR experience, XR tools, and, ultimately, the conclusion.

As a result of evaluation, studies focus on improving spatial ability, immersive learning & teaching, pedagogy, representation & criticism, informal approaches, and environmental developments; XR technologies used as VR, AR, MR, or VR & AR technologies; for VR technology Oculus Quest2, HTC Vive devices used as HMD and Gravity Sketch App, Unity Engine, GIS used as applications & software, for AR technology iPad & smartphones used as devices and Augment used as application; for MR technology HMD used as a device and scanning tool used as application. The conclusions of these studies can be categorized as positive and negative. The positive impacts of using XR technologies are enhancing the educational process for architectural design, creating a desire to learn, and leading to improved design education pedagogy. The negative impacts of using XR technologies are technical challenges as the system cannot handle multiple users simultaneously, which limits interaction; the IVE was only used for the critique sessions, not for the design process itself; students saw the AR tool as a challenging tool for integration in architectural education as a tool for representation, lacked the time necessary to understand the program entirely (Table 3.9).

Table 3.9 Paper 1 (Darwish et al., 2023: "Extended Reality for Enhancing Spatial Ability in Architecture Design Education") and review summaries.

Study	**The Focus of the Study**	**XR Experience**	**XR Tools**	**Conclusion & Projection Comments**
Rev. Darwish et al., 2023	XR -technologies application on architectural experiences	various	various devices & apps	various: mentioned below
Res & Exp. Darwish et al., 2023	improving the spatial ability of students	VR & AR for element design (as a part of design problem)	VR- Oculus Quest2 (HMD)&Gravity AR–iPad&Augment	+: enhancing the educational process -: technical challenges
Nisha, 2019	pedagogy	VR for city spatial development maps	VR, HDM and GIS	+: enhancing design pedagogy
Zhang and Chen, 2019	immersive learning and teaching	VR environment to interact with designs	VR – HTC Vive, Unity, and VR package	+: creating a keen to learn -: limited multi-user support
Sopher et al., 2019	representation & critics	AR/IVE for presentation & critics (life-size experience)	AR- Immersive Virtual Reality Env.	+: increased productivity in design activities -: used for the critique sessions
Fonseca et al., 2016	informal approaches	using AR for representation	Not mentioned	+: students were enthusiastic about technology -: AR integration challenges
Lu and Ishida, 2020	environment development	MR to create VR furnishing on scanned real world	MR- Scanning tool and HMD	+: system receives favorable feedback

Paper 2: Impact of Extended Reality on Architectural Education and Design Process, Kharvari and Kaiser, 2022

In Paper 2, the study comprehensively examines the influence of extended reality (XR) technologies on architectural education and the design process outcomes. It classifies the findings into four distinct course types and posits that XR technologies positively affect various design stages and facilitate architectural learning. Utilized PRISMA guidelines and a modified PICO strategy for systematic review and research question formulation, included user studies on AR/VR in architectural education, excluding conceptual studies without participants.

The study emphasizes that VR, AR, and MR are transforming industries, including education. VR is defined as an immersive computer simulation, AR overlays digital information, and MR blends physical and virtual interactions. XR technologies have shown potential in various educational fields, but their integration into architectural education needs more consensus. This study aims to systematically review XR technologies' impact on architectural education and the design process.

The data extraction for the reviews included defining the authors of the articles and publication years, the design of the studies, the fields of application, the software and devices utilized, the specified results, and the number of participants. The articles were classified into four categories: "Construction and Building Science," "Design Education," "Lecture Courses," and "Other Courses and Applications."

The authors' investigation findings reveal that implementing XR technologies in architectural education enhances learning outcomes and student performance. Moreover, using VR, AR, and MR in this context positively influences the design process. XR technologies present students with an experience centered around their needs, resulting in substantial advancements in learning. To be more precise, immersive VR enhances spatial perception compared to non-immersive environments.

In the ideation stage, VR improves critical thinking and problem-solving. AR enhances the ability to mentally rotate objects, thus aiding in comprehending spatial relationships. MR, on the other hand, facilitates the evaluation and reflection stages of the design process. The employment of XR technologies fosters a more effective retention of architectural precedents. Additionally, VR stimulates contemplation on design, leading to an enhancement in the overall design process. Lastly, XR technologies are crucial in assessing the experiential and evaluative aspects of created spaces. More research is needed to quantify the impact of XR tech on creativity and idea generation (Table 3.10).

Table 3.10 Paper 2 (Kharvari, F., & Kaiser, L. (2022). Impact of XR on architectural education and review summaries.

Study	The Focus of the Study	XR Experience	XR Tools	Conclusion & Projections Comments
Kharvari and Kaiser, 2022	XR -technologies (VR, AR, MR) application on experiences	various	various devices & apps	+: affordability, efficiency, enhanced learning -: creativity, idea generation, psychological studies required
Kharvari and Hohl, 2019	space/site visit/built-environment experience	serious gaming using VR applications for 3D	VR-HTC Vive & Unreal Engine	0: Not mentioned
Ozgen et al., 2019	learning problem solving	VR for basic design education	VR- Oculus RiftDK2, Google Blocks	+: VR boosts problem-solving in interior architecture
Hopfenblatt & Balakrishnan, 2018	teaching problem solving	VR for foundation studios in learning, adapting, and prototyping	VR- ZSpace, HTC Vive, Nine Cube VR	+: useful for design creation, simplified teaching without 3D software
Llorca et al., 2018	teaching importance of sound in urban spaces	urban acoustics education	VR- Oculus Rift, music	+: enhanced satisfaction, and space awareness via VR, opportunity to feel-in-place
Huang et al., 2018	learning/exploring about an urban space	integrating agent-based modeling with VR for learning	VR- HTC Vive	+: enhanced design process
Abu Alatta & Freeman, 2017	learning early design process	enhancing spatial perception within the design process with IVE	VR-General, Oc. Rift, Unity3D	+: improving performance, creativity, and overall design quality
Fonseca et al., 2017	motivation	tech adaptation of the student with 3D visualization	not mentioned	+: advanced visualization improved motivation
Valls et al., 2017	exploring/creating/experiencing	improving student motivation	AR- Unreal Engine 4	+: gamification or serious game strategies in VRE creates motivation
Paes et al., 2017	experiencing/exploring	IVE for understanding of architectural 3d models	VR & IVR- 3D model, VR techs	+: IVR provides better spatial perception conventional
Sun et al., 2017	experiencing in VR /AR	VR technologies for online AE	Not mentioned	+: VR technologies are better than conventional
Fonseca et al., 2016	experiencing via VR-AR-DS hybrid	informal interactions in 3d education	AR/VR/DS/HM	+: boosted motivation, enhanced graphics & spatial skills for academic success
Valls et al., 2016	learning via VR	Videogame technology for learning	VR- Unreal Engine 4	+: create a speculation on method & tools
Ayer et al., 2016	experiencing design via VR, AR and conventional	AR gaming for sustainable design education	VR/AR – Game ecoCampus	+: reduced time frustration, diverse design thinking breaks fixation
Sanchez Riera et al., 2015	evaluating presentations on site by using AR	Geo-located teaching using AR	AR- 3d models	+: low degree of immersion provided by these devices
Yoon et al. 2015	teaching drawings by using AR	AR in design communication	not mentioned	+: teaching orthographic projection with AR, enhancing spatial skills

Paper 3: Framework for the Use of Extended Reality Modalities in AEC Education, Spitzer et al., 2022.

The article presents a theoretical structure for Architecture, Engineering, and Construction (AEC) instructors to proficiently incorporate Extended Reality (XR) technologies into their educational plans. This framework amplifies the process of acquiring knowledge and fosters active participation. Its implementation in a Georgia Institute of Technology summer camp substantiates this proposed framework.

AEC professions hold great significance in society. Architectural Engineering and Construction Management are renowned for their substantial financial benefits and profound societal influence. In the realm of AEC education, XR technologies are progressively being employed to augment recruitment, retention, and student involvement. This is occurring despite the obstacles encountered in adopting such technologies and the absence of instructional guidance provided to educators.

A thorough examination of the existing literature was undertaken to comprehensively understand XR technologies and their various applications within AEC education. The authors employed the Model of Domain Learning (MDL) as a theoretical framework to connect AEC's educational objectives with XR's modalities. Subsequently, a framework for decision-making was constructed to assist AEC educators in selecting appropriate XR technologies based on their academic goals and priorities. To ensure the validity and effectiveness of this framework, it was implemented and tested during a summer camp held at the Georgia Institute of Technology's School of Building Construction.

The study conducted by the authors yielded several outcomes. First and foremost, XR technologies were defined, and their advantages and disadvantages for AEC education were clarified. Second, a decision-making framework for selecting XR modalities in AEC education at a summer camp was validated. Third, it is demonstrated that XR technology can enhance student engagement, self-confidence, and learning outcomes through immersive experiences. Lastly, immersive XR modalities such as IVR and MR are particularly effective in generating interest.

In conclusion, XR technologies have the potential to significantly enhance AEC education by improving comprehension, involvement, and professional visualization. The decision-making framework assists educators in determining appropriate XR modalities for different educational objectives. Using XR to generate interest may result in heightened motivation and continued engagement in AEC curricula. Given the rapid progress of XR technologies, it is imperative to update the decision-making framework continually.

The reviewed studies generally include architectural engineering education, and there could not be any related to design education, so Paper 3's reviews are not in the framework of this study (Table 3.11).

Table 3.11 Paper 3 (Spitzer, B. O., Ma, J. H., Erdogmus, E., Kreimer, B., Ryherd, E., & Diefes-Dux, H. (2022). Framework for the use of extended reality modalities in AEC Education. Buildings,) review summary.

Study	The Focus of the Study	XR Experience	XR Tools	Conclusion & Projections Comments
Spitzer et al., 2022	XR - technologies (VR, AR, MR) application on architectural experiences	various	various devices & apps	+: XR increases student interest and so engagement -: XR for improved learning is more complicated to achieve and measure. control groups are needed 0: XR interventions should only partially substitute the conventional teaching methods. 0: if interventions are more likely to increase engagement, self-efficiency, and learning of students.

The synthesis of three distinct papers on Extended Reality (XR) applications in architectural education reveals multifaceted insights into its impact and utilization within design studio contexts. The results of the systematic literature review can be summarized as:

- XR technologies can be used for various pedagogical components in architectural design studios.
- XR technologies (VR, AR, MR) have been utilized individually or in combination, but no study involving all three was found.
- The use of XR technologies (VR, AR, MR) in a complementary system is limited and has mainly been applied in partial stages of the design process.
- XR technologies are limited and experimental within architectural design studio education.
- No study was found comparing experiences with XR technologies to all components of conventional design studios.
- In experiences with partial architectural design studio education using XR technologies, disadvantages related to device and hardware health effects can occur.

- Overall, experiences with partial architectural design studio education using XR technologies have resulted in positive student learning outcomes and effective teaching by instructors.
- The studies conducted within the framework of 'XR Experience in Architectural Design Studio Education' are primarily experimental, have partially addressed education components, and are limited in terms of published works.

The papers collectively emphasize the beneficial impact of XR technologies on architectural education. While Paper 1 concentrates on enhancing spatial ability through VR and AR experiences, Paper 2 investigates the broader influence of XR (VR, AR, MR) on various design stages. Paper 3 offers a theoretical framework for integrating XR modalities (IVR, MR) into architectural education, targeting improved learning experiences and engagement (Table 3.12).

Table 3.12 Evaluation of reviewed papers' pursuit results.

Paper	Pursuit	Findings
1 Darwish et al., 2023	enhancing spatial ability via XR experience	implementing XR technology in early architectural design education significantly enhances students' spatial ability levels
2 Kharvari and Kaiser, 2022	understanding Influence of XR on various design stages	XR technologies enhance learning outcomes and student performance
3 Spitzer et al., 2022	creating theoretical framework for integrating XR modalities into architectural education	proposes a decision-making framework for AEC educators to select suitable XR technologies for various educational outcomes

The tools utilized across the papers—from Oculus Quest2 and HTC Vive to iPad, smartphones, and applications like Gravity Sketch, Unity Engine, GIS, and Augment—showcased significant potential in enhancing architectural pedagogy. These tools positively influenced spatial perception, critical thinking, problem-solving, and student engagement, thereby improving learning outcomes in architectural design education.

Overall, the studies highlight the positive impacts of XR technologies in enriching architectural education. Students perceived XR experiences as motivating, enjoyable, and conducive to enhanced learning. However, technical limitations, such as the inability of XR systems to accommodate multiple users simultaneously, hindered collaborative interactions, suggesting a need for improved multi-user capabilities for a more seamless educational experience.

Despite the positive impacts identified, notable gaps remain. The studies primarily focus on architectural engineering education, needing more emphasis on design education specifically. Moreover, none of the papers integrated all three XR technologies (VR, AR, MR), presenting an opportunity for a more holistic approach. Addressing technical challenges and conducting comparative assessments between XR and conventional methods could provide deeper insights into XR's efficacy in architectural design education. More attention should be given to examining the harmful effects of device and hardware usage on health in the context of XR technology (Table 3.13).

Table 3.13 The Summary of the Impact of the XR on ADSE Systematic Review Findings.

	Findings
Educational Impact	• Boosting students' spatial capabilities. • Enhancing critical thinking and problem-solving abilities within the design process. • Elevating levels of student engagement and active participation.
Positive Outcomes	• Enhancing the effectiveness of education and improving student performance. • Increasing students' learning motivation. • Enriching experiential learning.
Challenges	• Technical limitations, especially the inability to support multi-user environments. • Health issues related to device and hardware usage. • Challenges in integrating XR technologies into all educational components.
Research Gaps	• Lack of studies that use all components of XR technologies (VR, AR, MR) together. • Lack of studies focused on design education. • Lack of comparative assessments between XR technologies and conventional educational methods.
Future Directions	• Holistic integration of XR technologies in education. • Improving technical capabilities and multi-user interactions. • In-depth examination of health effects.

The reviewed papers shed light on the evolving architectural design education, particularly emphasizing the transformative impact of XR technologies. Although these studies show promising results, certain critical areas require further exploration and consideration.

It is important to note that the studies reviewed focused on architectural engineering education rather than design education. Future research must expand the scope to include design-centric educational contexts, as this would provide valuable insights tailored to design studio pedagogy.

None of the reviewed papers incorporated all three XR technologies (VR, AR, MR) in a unified educational context. Taking a more holistic approach and exploring the combined impact of these technologies could yield comprehensive insights into their synergistic effects. Moreover, conducting comparative assessments between XR and conventional educational methods would enhance comprehension of the effectiveness of XR in architectural education.

Efforts should be made to advance XR systems' technical capabilities to facilitate seamless multi-user interactions. Enhancing XR technology to support collaborative learning environments can significantly enhance its effectiveness in design studio education.

In conclusion, while XR technologies are promising to enhance architectural design education, further research is needed to address specialized design contexts, achieve holistic integration of XR technologies, and make technological advancements. The evolution of XR holds immense potential in revolutionizing pedagogical approaches and fostering enhanced learning experiences within architectural design studios.

The research found limited studies on this topic with "XR technologies" and "architectural design education" keywords. As a result of the systematic review, three articles remained.

Extended Reality (XR) experiences in the architectural design studio education context; this study investigated whether enhancing the components of conventional design studio education using XR technologies is possible and beneficial, how XR technologies have influenced design studio education, and if it provides valuable insights that enhance experiential learning and highlight the advantages and challenges of this innovative approach.

This study guides students, educators, and researchers in navigating the dynamic intersection of XR technologies and architectural design studio education. The papers and their reviewed studies observe that experiences were generally conducted on one or more components of design studio education; generally, one of the XR used and using XR technologies generally resulted in positive outcomes.

In conclusion, XR's experiences in architectural design studio education are promising. As experiments, experiences, and research progress continue, there is a high potential to develop these outcomes further, thus suggesting a solid potential for an alternative approach to conventional design studio education (Figure 3.9).

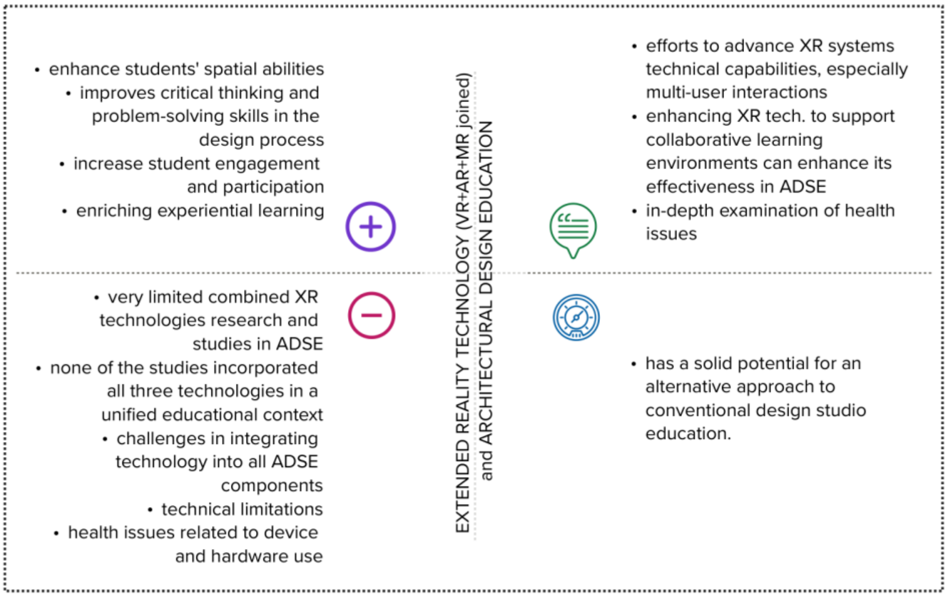


Figure 3.9 Conclusion of XR Technology and ADSE Review.

3.5 A Holistic Evaluation of XR Technologies in Architectural Design Education

The systematic reviews underscored the transformative potential of VR, AR, MR, and XR technologies in enriching the architectural design studio experience, providing a robust foundation for future research and practice in this evolving field (Figure 3.10).

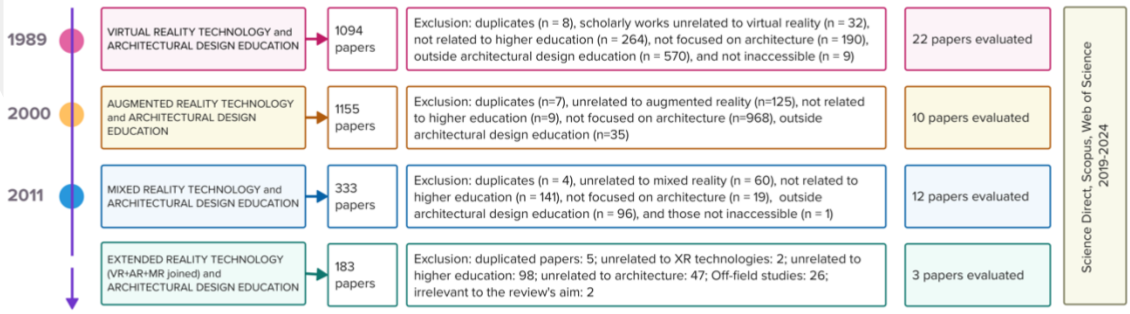


Figure 3.10 Conclusion of VR, AR, MR, XR Technologies, and ADSE Review.

Integrating virtual, mixed, augmented, and extended reality (VR, MR, AR, XR) technologies into architectural design education has demonstrated numerous common benefits and challenges. These technologies have been shown to positively impact students by enhancing spatial understanding, cognitive skills, and design proficiency, all of which are crucial in architectural education. They also promote creativity, critical thinking, and problem-solving abilities, making them powerful tools for improving learning outcomes. Furthermore, these technologies' immersive and interactive nature significantly boosts student engagement and participation, offering a more enriched experiential learning environment that aids in better comprehension of architectural concepts. Recognized for their transformative potential, VR, MR, AR, and XR technologies are key to shaping architectural education's future by introducing innovative approaches to conventional studio methods.

However, despite these advantages, integrating these technologies is not without challenges. Usability concerns, cognitive load, high costs, the need for specialized training, and technical limitations are common issues that must be addressed. Additionally, health-related concerns associated with prolonged use of these devices pose significant challenges. There is a broad consensus that further research and exploration are essential to fully realize these technologies' potential in architectural education. Addressing these challenges and optimizing the integration of these technologies into the curriculum are critical steps toward their successful and widespread adoption. In summary, while VR, MR, AR, and XR hold immense potential to revolutionize architectural design education, their successful implementation requires careful consideration of the associated challenges, particularly regarding usability, cost, training, and health implications.

Following the exploration of the theoretical benefits and challenges associated with XR technologies in architectural design education, the next section focus on a practical case study that examines the application of these technologies in a real-world educational setting. In this experiential study, XR tools such as video games, screens, and virtual/augmented reality headsets are employed to create immersive design environments within the architectural studio for design experiences. The study also incorporates platforms and software that enable design using these tools, embedding architectural knowledge within a game format to test whether students can effectively acquire this information through gameplay. The study evaluates the design processes and outputs across various realities by providing three different design problems, each set in distinct environments but comparable in scale, concept, and difficulty. This approach allows for identifying the strengths and weaknesses of XR technologies as a potential next evolution for the conventional design studio, laying the groundwork for future modeling and educational advancements.

Chapter 4

Architectural Design Education through (XR) Technology

The integration of Extended Reality (XR) technologies, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), has significantly influenced various fields, particularly architectural design education (ADSE). As architectural education progresses with technological advancements, it becomes increasingly important to understand how these tools affect students' design processes and learning outcomes. This chapter aims to provide an in-depth examination of the impact of XR technologies on ADSE.

The potential of XR technologies in architectural education lies in their ability to enhance visualization, foster creativity, and improve spatial understanding. Literature reviews have shown that XR can greatly aid in understanding complex spatial relationships, detecting design errors early, and promoting collaborative efforts among students. Despite these benefits, practical implementation faces challenges such as technical issues, ergonomic concerns, and the need for effective integration with conventional design tools.

Unlike the studies reviewed in the literature, this research aims to create a cohesive and immersive design process by using various XR technologies. While previous approaches typically use each XR environment in isolation, this study seeks to harmonize these technologies to create a seamless, holistic educational journey. The literature reveals no precedent for such a unified application of XR, making this research a pioneering effort to transform these technologies into a continuous and richly integrated learning experience.

In this study, integrated fictions were developed to use XR technologies for design studio education. In this context, first, a video game (using VR) was designed and implemented to embed architectural knowledge within the game. The purpose of this game is to help students understand this knowledge before starting their design work, raise their awareness, and stimulate their curiosity through gameplay. This would lead them to further research after playing the game while also facilitating visual and experiential learning and preparing them to design in XR environments. In conventional design studio education, this process is typically achieved through literature review lists, topics, project research, and technical research recommendations provided to students in the first week of the course. However, in this study, the aim is to conduct these processes digitally through gameplay.

Secondly, a system was set up to enable students to design in VR and/or AR environments using screens and VR/AR headsets, allowing them to choose whether to design in VR or AR environments. The Arkio platform—a cloud-based platform developed for architects and designers, enabling 3D modeling and collaboration in virtual and augmented reality (VR/AR) environments—was used for this process. In this setup, students experience design using these tools.

Due to the lack of a similar platform or software that could be used with MR environments and tools, the research focused on comparing conventional design studios with VR and AR environments and tools (video game + screens, video game + VR/AR headset; with both screens and headsets providing either VR or AR environments, depending on the students' preferences). The case study was designed to compare different environments and tools and assess their impact on the design experience, process, and outcomes. This empirical investigation provides evidence of the benefits and challenges of adopting or using extended reality technologies, offering insights into their effectiveness as educational tools in the design studio.

The scope of the case study was limited to a small number of students due to constraints on the number of devices and the process required for the experience. Therefore, a call for voluntary participation was made exclusively to AGU Architecture students at the 2nd, 3rd, and 4th levels -who have passed the basic design-. Three design problems were prepared for each environment, all of which are small in scale and relatively simple. Considering that all the students had already completed their basic design education, 4-8 hours were allocated for each task. The within-subjects design methodology was selected, allowing students to serve as their own control group, enabling them to design individually in three different environments and compare their experiences. A tripartite data set was envisioned in this study to implement this method and strengthen the accuracy of the findings. This data set involves collecting information through open and closed-ended surveys regarding students' experiences, using observation charts designed by the researcher during the design process, and evaluating the design products using rubrics.

Today and in the future, translating architectural design studio education into different realities requires consideration of many components. In addition to the many components inherent in the nature of the design studio education, alternative realities also encompass numerous components within themselves. Achieving a complete outcome by evaluating all components together requires more experiments, experiences and more research. Experiencing and evaluating all components together is a challenging task because these components need to exist independently and also interact with each other. Therefore, in this study, the design studio has been addressed with its components of space, tools, design process, and production, considering the student as an individual designer, while components such as hidden content, other people, interactions, peer relations, etc., have been disregarded.

In this context, this experiential study explores how XR technologies influence the design experiences of architecture students. Utilizing a within-subjects design methodology, the research involves 11 architecture students from AGU who engage with three different design environments: conventional tools, screens (VR/AR), and VR/AR headsets. Data collection methods include surveys, observations, and product assessments to evaluate the impact of XR on student engagement, design proficiency, and overall satisfaction. This study aims to assess the educational benefits and challenges of using XR technologies in architectural design education. It provides deep insights into the broad application of these innovative tools in education by examining the motivations and objectives behind their adoption. The findings highlight the significant advantages of XR technologies in areas such as visualization, student engagement, and innovation; however, they also emphasize the need for improvements in usability and ergonomics. This research contributes substantially to the ongoing discussion on the future of architectural education in the digital age, revealing the transformative potential of XR technologies.

Research Title: Extended Reality Technologies and Design Experience

Research Question: How does the use of extended reality (XR) technologies impact students' architectural design experiences?

4.1 Case Study Methodology

In this experience-focused case study, a within-subjects design methodology was adopted due to the limited number of participants and the process-oriented nature of the experiment. A data collection set comprising survey, observation, and product assessment methods was implemented to obtain more accurate findings from this experiment. (Figure 4.1).

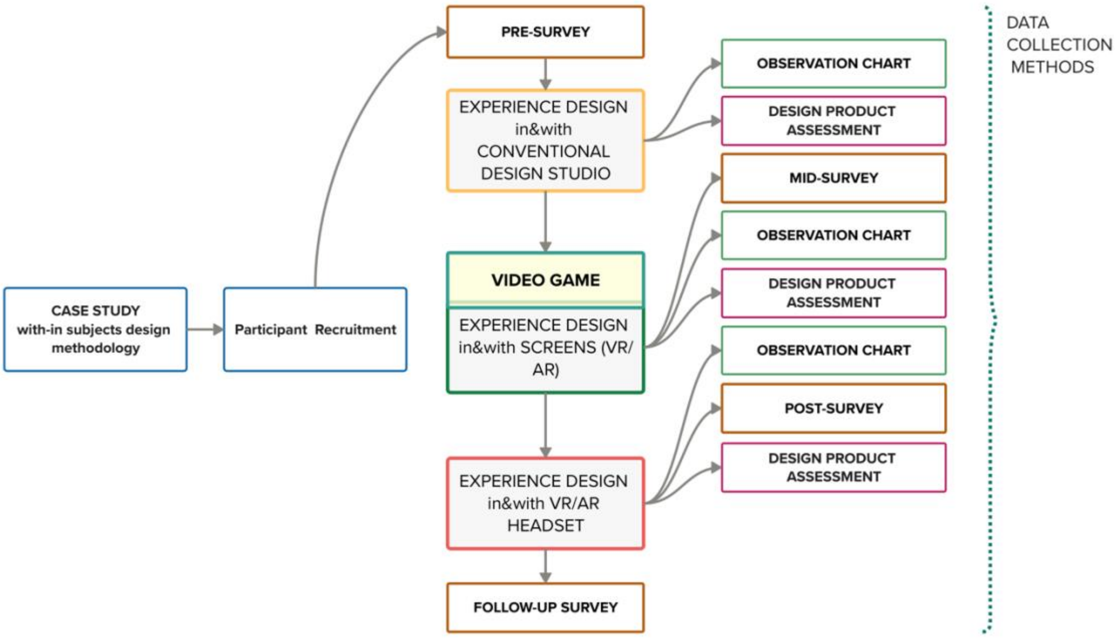


Figure 4.1 Case Study Methodology Map.

4.1.1 Case Methodology and Design

The within-subjects design methodology is an educational research approach in which every participant is exposed to all the conditions under investigation. This approach in educational studies aims to evaluate the effects of interventions, teaching techniques, or learning environments within a single participant or group. Unlike designs with separate groups experiencing different conditions, each participant serves as their own control, offering a more holistic understanding of individual responses to various educational factors (Creswell, 2014).

This study chose the within-subjects design methodology to assess interactions with XR technologies. This method ensures that each student interacts with all design environments (conventional environment, screens (VR/AR), and VR headsets), thereby reducing variability due to individual differences and enabling more consistent comparisons. This strategy minimizes variability stemming from skill differences, preferences, and prior experiences, allowing for a more precise evaluation of the impact of each design environment.

With-in-subjects design methodology allows for direct comparisons by having each student act as their own control across all conditions, thereby revealing subtle distinctions and preferences among environments. Thereby, clearer insights are gained into how each environment influences a student's design process, satisfaction, and perceived innovation. Additionally, within-subjects designs are more efficient and feasible, requiring fewer participants to achieve the same level of statistical significance.

This approach also facilitates comprehensive feedback from participants across different environments, providing holistic insights into their experiences and perspectives. Exposing students to various design tools enhances their engagement and learning, potentially improving their overall design competencies. The method allows for extensive data collection, as students can reflect on their experiences with different tools and environments, leading to deeper insights into educational impacts. This research focuses on subjective measures such as satisfaction, perceived innovation, and personal preferences, which are best evaluated when individuals engage with all conditions. The approach helps to uncover nuanced personal responses to each environment.

In summary, the within-subjects design methodology offers a more controlled, efficient, and comprehensive assessment of how different design environments influence the same student for this case study. This strategy enhances the reliability of the results and provides more detailed, personalized insights into the educational impacts of XR technologies in architectural design education (Figure 4.2).

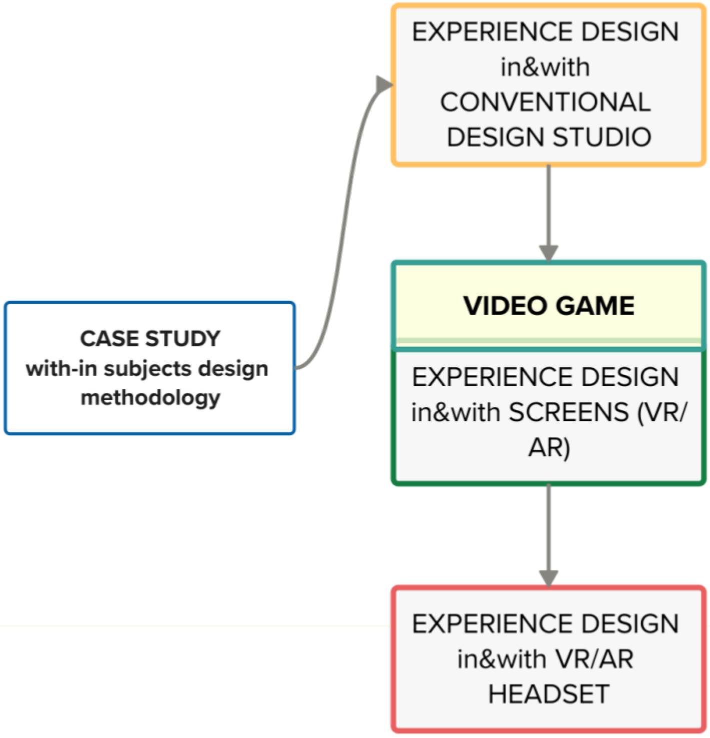


Figure 4.2 Adopted Within-Subjects Design Methodology for Case Study Application.

4.1.2 Data Collection Methods

The study employed three data collection methods—surveys, observation charts, and output assessments—to comprehensively understand student experiences with XR technologies in architectural design. Surveys captured students' perceptions, experiences, and satisfaction with the design tools and environments, providing personal insights into their interaction with the technology. Observation charts, filled by the researcher, objectively recorded how students interacted with different tools and environments in real-time, helping to validate and complement the survey data. Product assessments evaluated the quality and effectiveness of the design products created by students in each environment, measuring aspects such as creativity, functionality, spatial efficiency, technical proficiency, and representation (Figure 4.3).

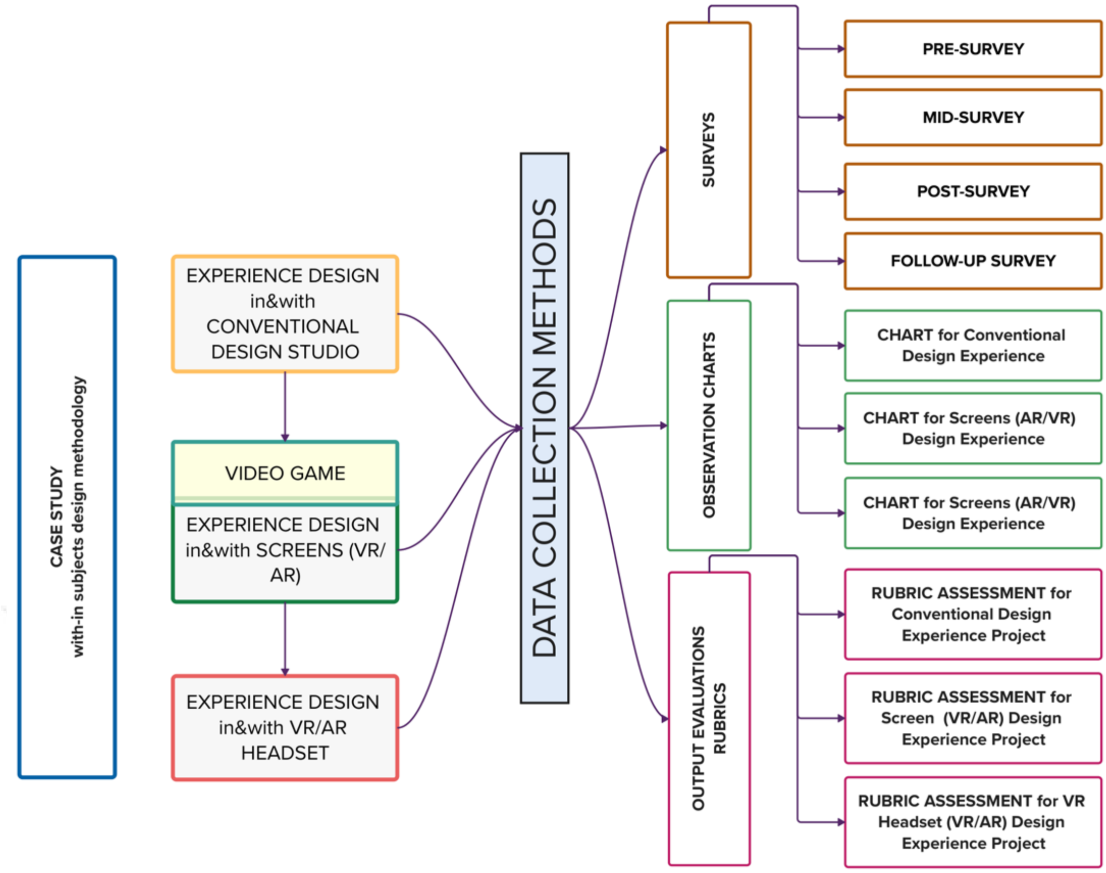


Figure 4.3 Experience and Data Collection Process.

This combination of methods ensured a holistic and detailed evaluation of the impact of XR technologies on architectural design education, leading to more reliable and nuanced conclusions.

4.1.2.1 Surveys

Surveys are a frequently employed method designed to gather in research. They aim to gather information from participants by utilizing structured questions. The primary objective is efficiently amassing quantitative data from a broad participant base. Surveys are adaptable and implemented through diverse channels, such as paper, online platforms, or face-to-face interviews, encompassing various subjects (Babbie, E., 2016).

In this case study, four different surveys were employed to gather comprehensive data on participants' experiences and perceptions at various stages.

The survey studies were conducted using Microsoft 365's online Excel platform.

Pre-Survey (App-3.4)

The pre-survey established a baseline understanding of participants' familiarity with XR technologies, as well as their expectations and experiences with conventional design tools. This provided context for subsequent experiences and comparisons.

Students were asked to complete the pre-survey before starting the design experience.

Mid-Survey (App-3.5)

The mid-survey captured immediate feedback on engagement and the educational value of a video game using screens (VR/AR), helping understand the digital tool's impact and any necessary adjustments.

On the second day, after experiencing video game and design on screens of the design experiences, students were asked to complete the video game-related mid-survey.

Post-Survey (App-3.6)

After using conventional tools, screens, and VR headsets, the post-survey evaluated overall satisfaction, challenges, and preferences, providing comprehensive data on how each design environment influenced the participants' design process and innovation.

At the end of the design experience, students were asked to fill out the post-survey.

Follow-Up Survey (App-3.7)

The follow-up survey, which was conducted one week after the experiences, assessed the long-term impact on participants' architectural design skills and thinking. It determined the lasting effects of the XR interventions and their influence on design methodologies and skill application.

Using these surveys at different stages allowed to capture a holistic view of participants' experiences and development, ensuring a thorough understanding of the immediate and lasting impacts of XR technologies in architectural design education.

4.1.2.2 Observations (App-3.8)

As a data collection method, observation entails observing and documenting participants' behaviors, actions, or occurrences within a designated setting. This approach enables researchers to acquire direct information about natural events or behaviors. Observations can be structured or unstructured and may incorporate quantitative or qualitative analysis, depending on the research objectives. This methodology offers valuable insights into various phenomena, including those within social and educational contexts, and is frequently applied across diverse disciplines (Fraenkel et al., 2019).

Observation Charts

Gillham (2008) notes that these charts are instrumental in gathering data closely aligned with actual occurrences in the field, making them essential for studies requiring detailed observation. An observation chart, used as a data collection method, systematically captures observable behaviors, actions, or events in a structured manner throughout a study. This approach enables the documenting of real-time data within a natural setting, aiding in identifying and analyzing patterns. Observation charts are especially advantageous when direct measurement or self-reporting is difficult, as they offer an objective record of events as they happen.

The use of observation data in this study provided several key benefits, contributing to a more comprehensive understanding of student experiences with XR technologies in architectural design. Observation charts allowed to record students’ behaviors, interactions, and engagement with design environments in real time, providing objective data that could highlight patterns and behaviors not captured through surveys alone. This non-intrusive monitoring ensured that data reflected natural behaviors and interactions. By complementing the subjective feedback obtained from surveys, observation data offered a fuller picture of students’ experiences, enhancing the reliability and validity of the findings and helping to identify discrepancies between reported and actual behaviors. Observation charts systematically documented levels of engagement, interaction, efficiency, and challenges, quantifying metrics such as time spent on tasks, frequency of tool usage, and types of interactions. This method provided context-rich data, capturing nuances of the design process, non-verbal cues, collaboration dynamics, and immediate problem-solving strategies. Overall, observation chart data collection allowed researchers to obtain direct, objective, and context-rich data, complementing survey data and providing a more comprehensive and detailed understanding of students' design experiences, behaviors -adaption, motivation, etc.-, and challenges in different environments.

4.1.2.3 Output Evaluations

Product evaluation in research involves assessing and judging a specific product, service, or result to determine its effectiveness, quality, or suitability for a particular purpose. In educational research, this process may include evaluating tools, materials, programs, or interventions to determine their effectiveness and relevance (Scriven, 1991).

In the research context, analytical analysis refers to systematically examining and interpreting data to identify patterns, trends, or relationships. Depending on the data collected through various research techniques, this process can involve both quantitative and qualitative methods (Creswell, 2014).

In this study, output evaluation was employed to objectively assess the quality and effectiveness of students' design products. This method examined key aspects such as creativity, functionality, spatial efficiency, technical proficiency, and representation, providing concrete evidence of the impact of XR technologies on student work. Product evaluations validated the findings by complementing subjective data from surveys and observations and ensured a comprehensive analysis. Ultimately, product evaluation contributed to a more complete understanding of the educational outcomes and the effectiveness of different design environments.

4.2 Pre-Case: Transferring Architectural Knowledge Through a Game

A game design and application were developed to understand students' learning experiences through virtual environments. This study is designed for use before the middle phase of the case study -after the design experience in the conventional studio and before the design experience with VR or AR-. The aim is to measure whether this virtual video game teaches architectural knowledge, makes curiosity to research, and affects the student's design process, which they experience in VR/AR. Before developing the game application, extensive research was conducted on various aspects of game creation, including game design, game applications, game art, game engines, game mechanics, technical requirements, etc. (App-1: 1.1-1.14). After literature reviews and trial studies, the main game design decisions were completed to develop further; relevant data related to architectural education were selected and embedded within the game. (Figure 4.4).

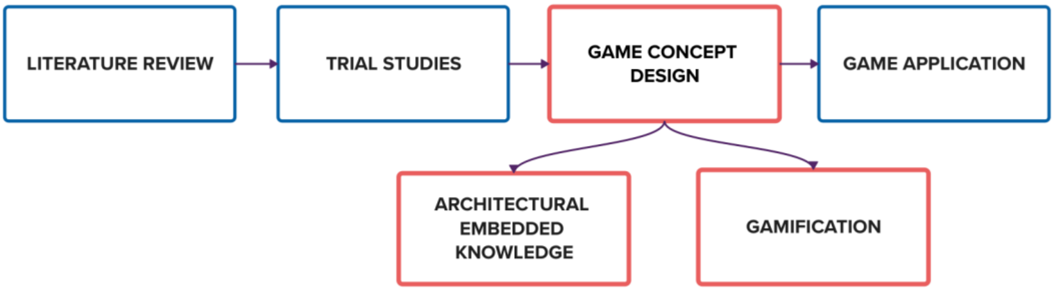


Figure 4.4 Video Game Design Process.

After all these preliminary studies, the game plot was prepared. Following the game plot, work on game design was undertaken, and finally, technical work was conducted to complete the game application

4.2.1 Game Concept Design

In architectural design studio education, students develop their architectural knowledge and experience in a design process that transitions from abstract concepts to concrete applications at the architectural scale. For students to effectively move from abstract to concrete, they need to research and learn the fundamentals of architectural knowledge, including art, culture, philosophy, ergonomics, built environment, dimensions, standards, natural environment, etc. This game imparts some fundamental knowledge through gameplay, focusing on architectural-embedded knowledge fiction and gamification. While the game provides brief information and experiences, the main goal is for students to gain visual familiarity after playing the game and to become curious, leading them to engage in more extensive literature reviews. The game fiction studies were developed through studies conducted in two main phases: Architectural Embedded Knowledge and Gamification.

4.2.1.1 Architectural Embedded Knowledge in Design Game

Typically, in Architectural Design Studios education, the resources listed in the syllabus are provided to assist students in conducting environmental analysis, obtaining information about building systems, and performing literature searches. Some of this information is embedded and visible in different parts of the game, designed to encourage students to engage with these resources, learn while having fun, and prepare to design in a VR/AR environment.

To create embedded architectural knowledge in the game, the game levels include elements that spark students' interest and curiosity in analysis studies, such as built environments, climate data, transportation, socio-cultural structures, and flora and fauna. Environmental data were incorporated into the levels to help students be aware of different environments, including different components, which can explain “belonging” issues in design.

The game's flashcard applications aim to illustrate some of the concrete information students need to acquire, stimulating their curiosity and encouraging them to research technical and architectural knowledge. In the flashcard applications, students only review the information to start the play stages.

In the stages, students are asked to rediscover the information depicted on the flashcards by playing. The stages are designed to enhance students' design principles and visual perception. The kind of mini-games for stages are preferred and designed depending on their known criteria to make the player familiar with and easier to motivate for the whole game.

The game's workflow contains sections that follow consecutively—level, flashcard, and stage— each serving as a prerequisite for the following (Figure 4.5).

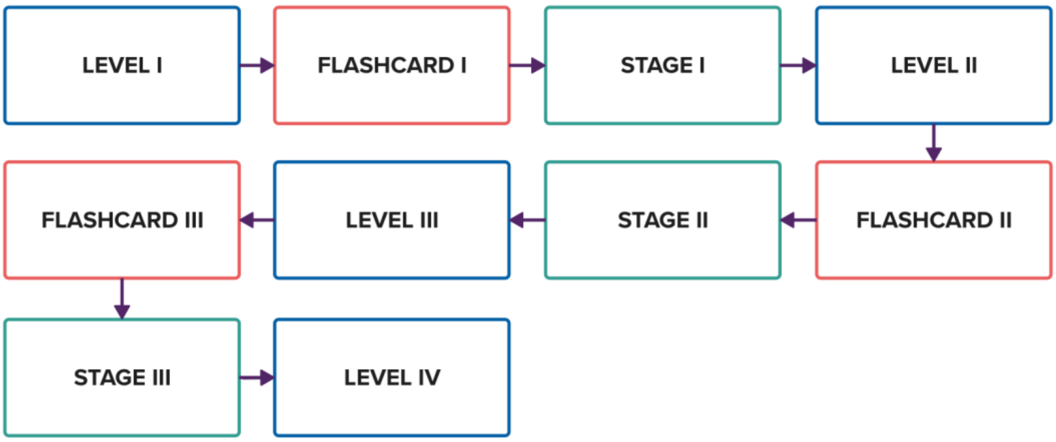


Figure 4.5 Sequential Game Play Flow.

This repetitive structure, with variations between stages, flashcards, and levels, aims to emphasize the necessity of general data for the design process and familiarize students with different reality environments through this application.

The game design includes various levels, flashcards, and stages, each with different objectives aimed at providing diverse environmental experiences and raising awareness about the dynamics and content of these environments. The game consists of four primary levels:

- Level I: Urban Environment-Includes Urban natural and built environment donations and dynamics.
- Level II: Town Environment-Includes the Town natural and built environment donations and dynamics.
- Level III: Forest Environment-Includes Forest natural environment donations and dynamics.
- Level IV: River Environment-Includes River natural and built environment donations and dynamics.

After each game level, a "flashcard" application precedes it, providing foundational architectural knowledge integral to the gameplay at each stage.

After each flashcard application, a stage presents a mini-game to reinforce the knowledge that the student reviewed on the flashcard.

Flashcard I: Architectural Artifacts (architectural history) - Students learn about known architectural artifacts.

Stage I: Architectural Artifacts - Students reinforce related knowledge through labyrinth game playing.

Flashcard II: Pavilions (architectural landmarks) - Students learn about known pavilion buildings.

Stage II: Pavilions - Students reinforce related knowledge by playing the matching game.

Flashcard III: Structural Systems (technical knowledge) - Students learn about structural systems.

Stage III: Structural Systems - Students reinforce related knowledge by playing the party game (Figure 4.6).

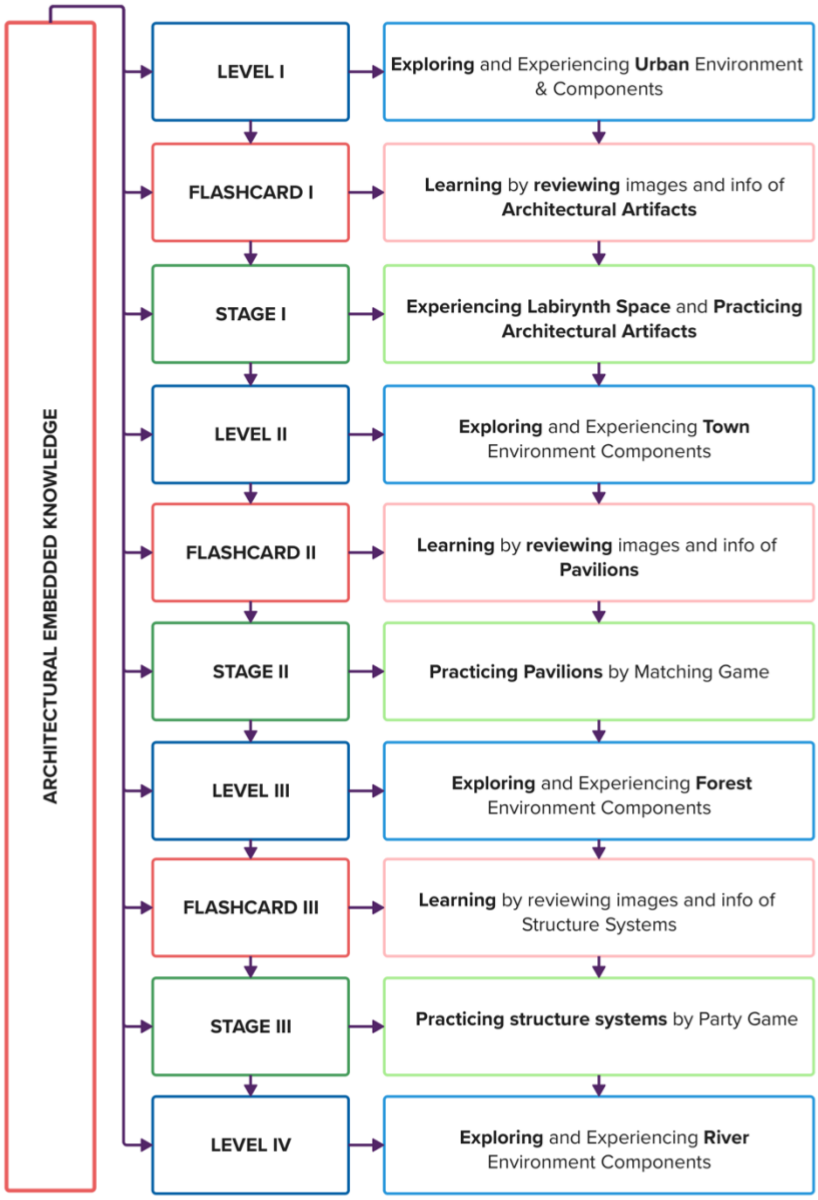


Figure 4.6 Game's Levels, Flashcards, and Stages and Architectural Embedded Knowledge Relations.

This structured game fiction aims to facilitate an engaging learning experience, allowing architecture students to acquire knowledge playfully and effectively.

Architectural artifacts, pavilions, and structural systems were selected for their educational potential, aesthetic qualities, cultural significance, and ability to inspire and engage players within the context of architecture and design. The pavilions highlight the diversity, innovation, and artistic expression in architecture, while the structural systems showcase a variety of construction techniques and materials, from conventional to modern approaches. These iconic examples were chosen for flashcards and stages to help students learn more about architecture through research. The digital drawings were visualized using Adobe Fresco to create game pieces suitable for engagement.

For the Flashcard I and Stage I, architectural artifacts were selected and drawn as below (Figure 4.7, 4.8, 4.9, 4.10):

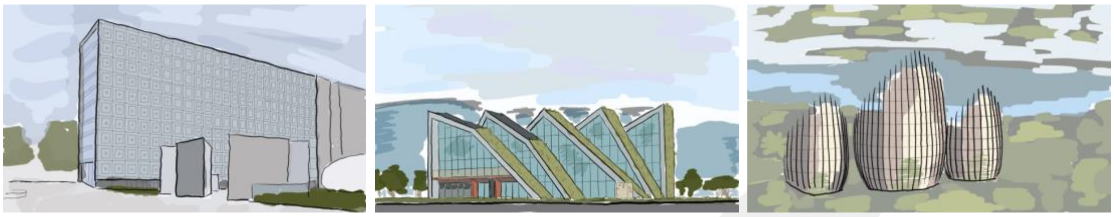


Figure 4.7 (from left to right) World Institute / 1981 -1987 / Paris, France / J. Nouvel Architecture Studio, G. Lezenes, P. Soria; Hualien Residence / 2018 / Hualien City, Taiwan / BIG – Bjarke Ingels Group; Jean-Marie Cultural Center / 1993 – 1998 / Noumea, New Caledonia / Renzo Piano.

Figure 4.8 (from left to right) He Art Museum / 2020 / Guangdong, China / Tadao Ando; House VI / 1975 / Cornwall, U.S. / Peter Eisenman; Secret Meeting of the Silent Creatures Proposal – the extension of the Alvar Aalto Museum / Finland / Toshiki Hirano.

Figure 4.9 (from left to right) Galleria in Gwanggyo / 2020 / Suwon, South Korea/ OMA; Peter B. Lewis Building / 2002/ Ohio, U.S. / Frank Gehry; Guggenheim Museum / 1939 / New York, U.S. / Frank Lloyd Wright.

Figure 4.10 Villa Savoye / 1928-1931 / Poissy, France / Le Courbusier & P. Jeanneret.

For the Flashcard II and Stage II, architectural artifacts were selected and drawn as below (Figure 4.11, 4.12, 4.13, 4.14).

Figure 4.11 (from left to right) Barcelona Pavilion / Ludiwig Mies van der Rohe & Lilly Reich; One Ocean Thematic Pavilion / Soma Architecture; Elytra Filament Pavilion / A. Menges & M. Dörstelmann.

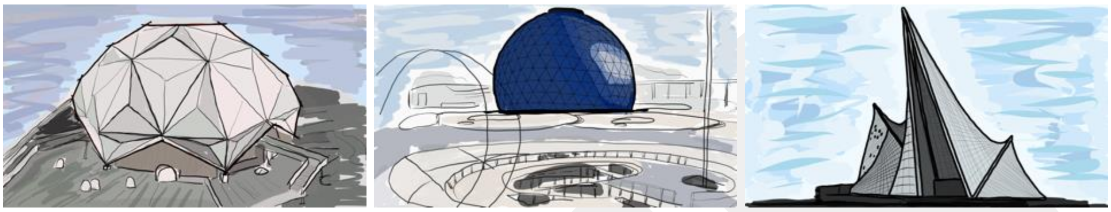


Figure 4.12 (from left to right) Pepsi Pavilion / E.A.T., R. Breer, F. Myers, R. Whitman, D. Tudor; Germany's Pavilion / Fritz Bornemann; Philips Pavilion / Le Corbusier.

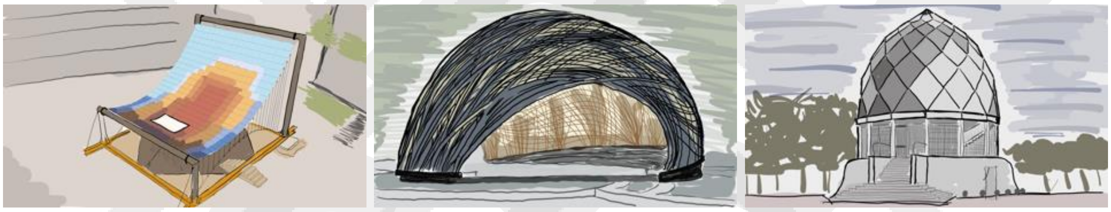


Figure 4.13 (from left to right) Solar Pavilion / V8 Architects & Marjan van Aubel Studio; The ICD & ITKE Stuttgart Research Pavilion / ICD & ITKE; Glass Pavilion / Bruno Taut.

Figure 4.14 Steampunk / Soomeen Design, I. Pantic & Fologram

For Flashcard I and Stage I, architectural artifacts were selected and drawn as below (Figure 4.15, 4.16, 4.17).

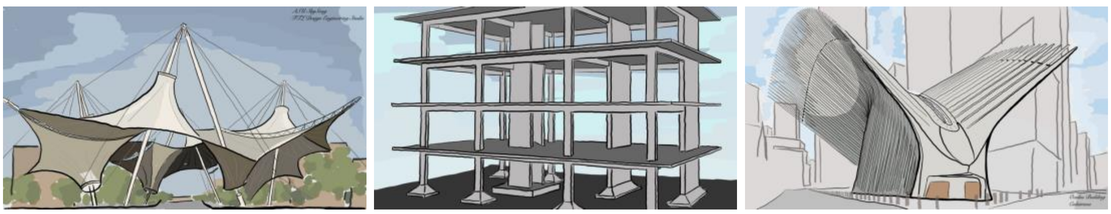


Figure 4.15 (from left to right) Tensile membrane; reinforced concrete carcass; steel (beams) carcass.

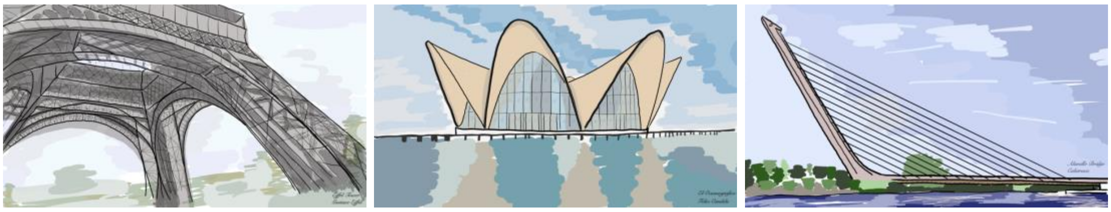


Figure 4.16 (from left to right) Trussed iron structural system; shell structural system; tensile structural system.

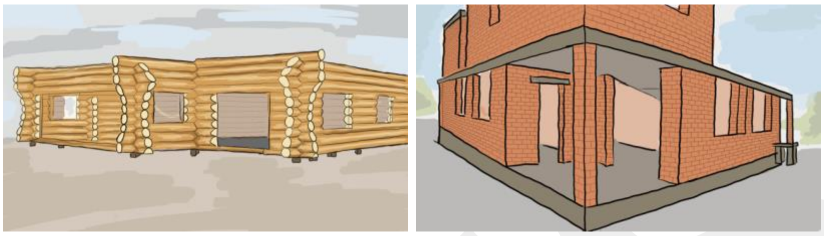


Figure 4.17 (from left to right) Wooden (log) masonry structural system; brick masonry structural system.

4.2.1.2 Gamification Strategy

Detailed work was conducted on the gamification phases before transforming the study into a technical game application. This section aims to create knowledge through game-playing to make learning more enjoyable for students.

A low-poly game is a type of video game that utilizes low-polygonal 3D models to create its visual environment. This modeling style is characterized by fewer polygons, resulting in simpler and more abstract forms. The low-poly aesthetic allows for faster rendering and reduced processing power and helps maintain focus on the educational content by minimizing distractions.

According to Tang et al. (2017), low-poly 3D modeling is particularly effective in virtual learning environments. The simplicity of the visuals supports a more efficient and focused educational experience. Thus, students can focus on the educational content without distractions. This style is also appropriate for expressing more stylized and symbolized architectural concepts and designs.

The game was envisioned to use drawings, assets, and features similar to the real world to reference real-world environments. This approach was intended to enhance students' environmental awareness. A platform and low-poly game style were chosen to ensure that real-world-referenced environmental components are perceived as practical and playable in the game environment.

A first-person perspective was used to enhance students' awareness of proportion and perception, and natural and built environments were decided to be used proportionally in real measurements. The single-player format chosen to allow students to work individually, personalizing their learning experience. Managing one's design processes is crucial because architecture requires complex thinking and creative problem-solving. The first-person perspective (FPS) enhances the personal perception of real-world ergonomics, measures, and scales, ensuring that all dimensions and data in the game accurately represent real-world standards.

Embedded architectural knowledge is acquired through racing and competing within the game. Architectural education requires students to understand physical dimensions and spatial relationships. Scaling and stylizing that replicate the real world allow students to realistically assess spaces while gaining practical experience in the design process.

In the levels, in addition to stylizing environments as low-poly references of real-world environments, the gamification design includes time-based challenges, creatures that roam and provide time bonuses when caught, coins placed to earn points, and interactions that result in health loss when colliding with people or various vehicles.

Flashcards were considered a requirement for passing stages, to be used before each stage and after each level. The goal is to make the information permanent by prompting students to think about how they will use it while scanning the flashcards. Flashcards are designed to present information visually with a small note, developing and strengthening the student's visual memory.

Stages are envisioned as mini-games in which the Z-generation is familiar with the game and where the information scanned in flashcards is applied. These stages are composed of both two-dimensional and three-dimensional games. The aim is to reinforce the information provided in the flashcards.

Based on the game concept design studies and the research, the general game map draft was created to follow the in-game application studies (Figure 4.18).

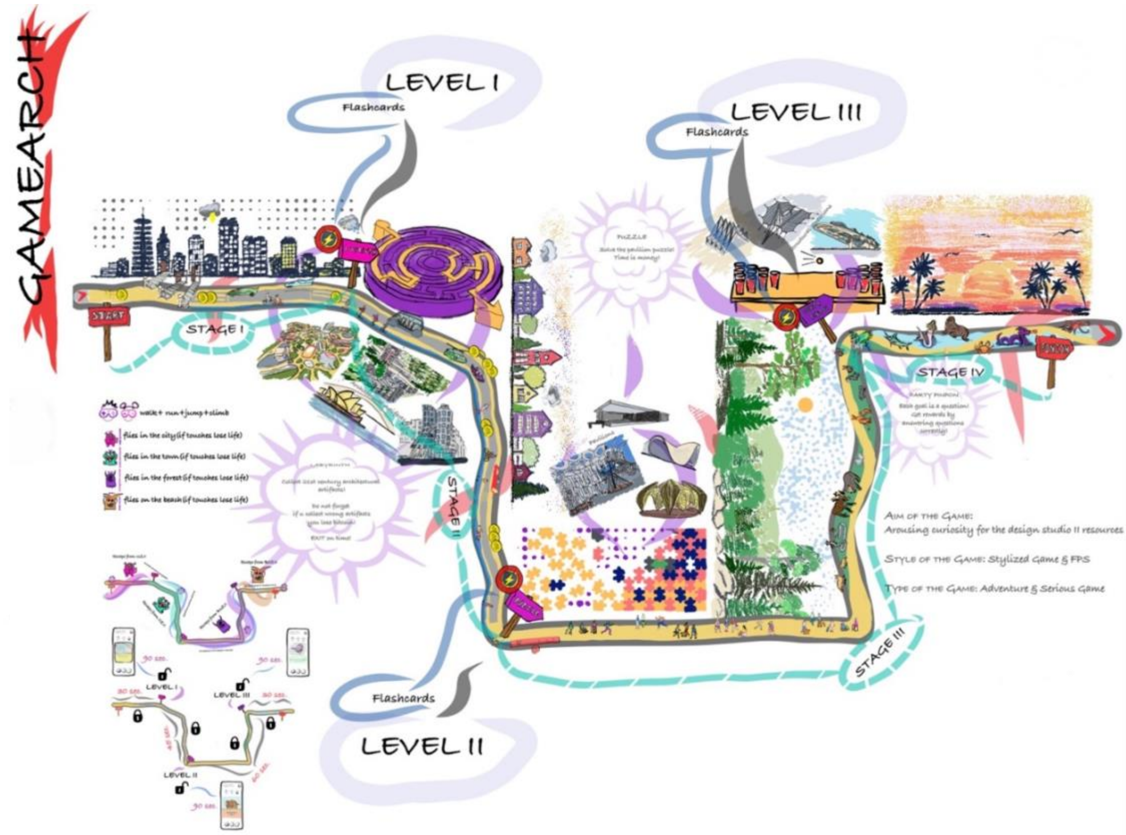


Figure 4.18 Game map draft.

This game map draft explains how levels, flashcards, and stages would flow within a single game. The game content illustrates information related to the visuals for each level, flashcard, and stage, including task descriptions and rules.

The game begins with the player in the first level, where they must find an exit within a given time in an urban environment. During this task, players lose health if collides with moving objects—such as vehicles, people, or animals. If players catch the monster roaming the area, they gain extra time. Collecting coins scattered around the area will grant them bonus points at the end of the game. If the player fails to complete this section, they must restart the level. However, if they succeed, Flashcard 1 appears. The player is presented with images of iconic architectural artifacts in this flashcard application. After viewing all the artifacts, they can proceed to play Stage 1. In Stage 1, the player's task is to find the images of the architectural artifacts from Flashcard 1 on the walls of a labyrinth and exit the labyrinth within the given time.

Upon completing the labyrinth task, the player progresses to Level 2, where they must find an exit from a town environment within the allotted time. During this task, players lose health if collides with moving objects—such as vehicles, people, or animals. If they catch the monster roaming the area, they gain extra time. Collecting coins scattered around the area will grant them bonus points at the end of the game. If the player successfully finds the exit from the town, they are presented with Flashcard 2. In this flashcard application, the player is shown images of pavilions as architectural landmarks. After viewing all the pavilion images, the player can play Stage 2. In Stage 2, the player faces a matching game where they must correctly match pavilion images with their corresponding information within the given time.

Once the Stage 2 task is completed, the player can start Level 3. In Level 3, the player must find an exit within a forest environment in the allotted time. During this task, the player lose health if collides with moving objects—such as animals. If they catch the monster roaming the area, they gain extra time. Collecting coins scattered around the area will grant them bonus points at the end of the game. After completing Level 3, the player is presented with Flashcard 3, which features images of structural systems. After viewing all the images, the player can start Stage 3. In Stage 3, the player participates in a party game. During this game, images and legends of structural systems from Flashcard 3 are displayed. The player must throw a ball into the cup that matches the color of the legend on the displayed image within the given time.

After passing Stage 3, the player reaches the final Level 4. In Level 4, the player must experience the river environment and walk across a bridge without falling into the water to reach a well. If the player falls into the water, they lose health and must restart the level; if successfully reaches the well completes the Gamearch game, and the player can see their score on the scoreboard.

Through the studies that were conducted, the game flowchart was developed and finalized (Figure 4.19).

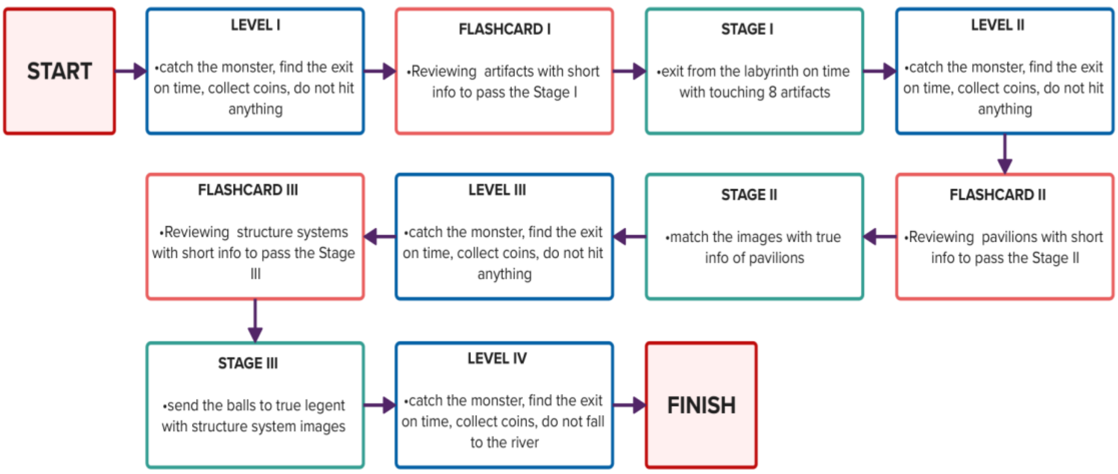


Figure 4.19 Advanced Game Flow.

After the game flow studies, an advanced game map is designed for the interfaces, and the information, guidance, and interactions provided through these interfaces are used to prepare the application. This section includes a detailed game operation map and illustrates how the UI (User Interface) and UX (User Experience) could be. The Game Operation Map illustrates the flow of the player's journey through the game, highlighting key interfaces, actions, and decisions. Each numbered item represents a specific screen or interaction, guiding the player from the game's start through various levels, stages, and content reviews. The accompanying legend provides concise descriptions, clarifying the purpose of each step and ensuring a seamless, intuitive user experience (Figure 4.20) (Detailed Version and Legend App-1.13).

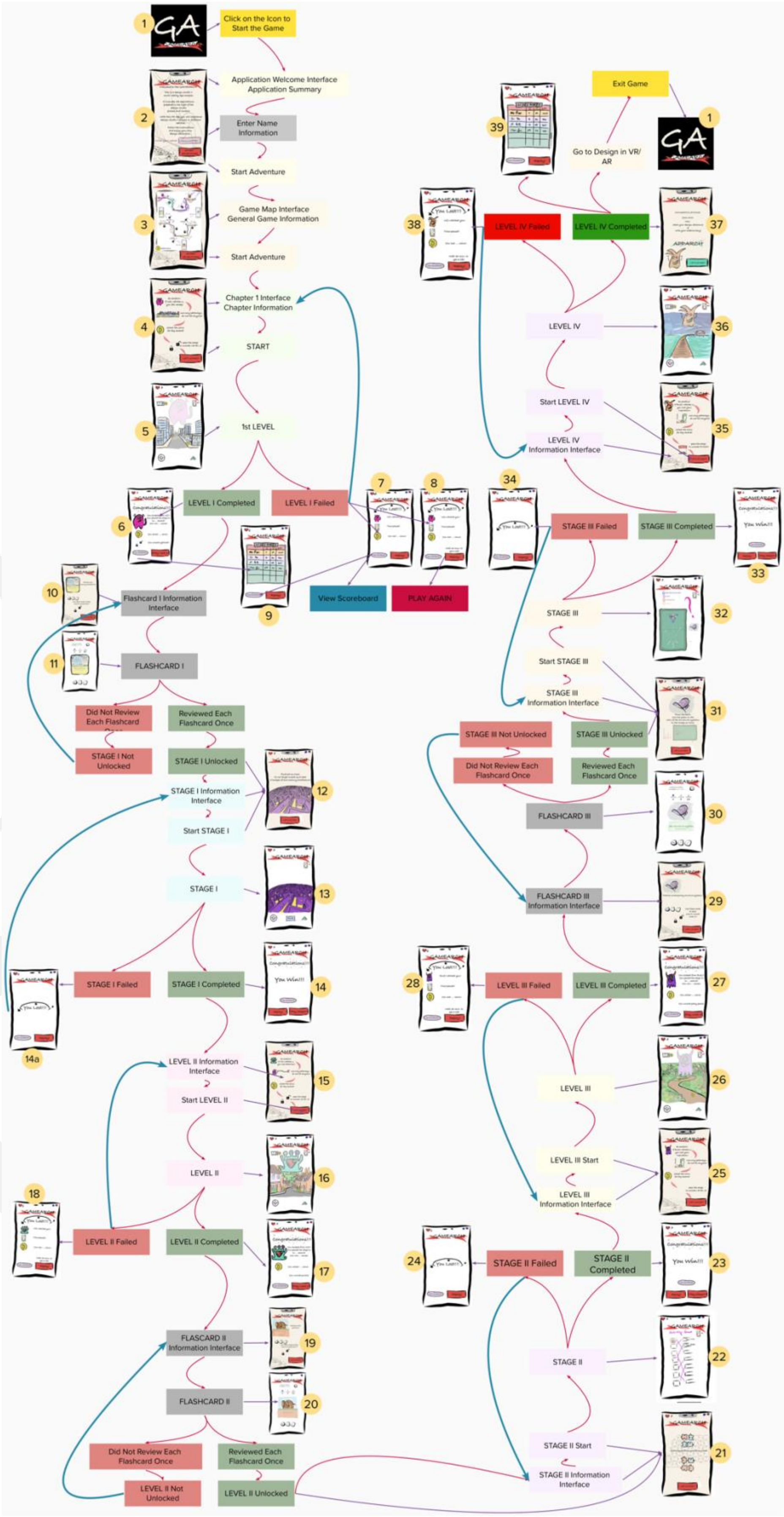


Figure 4.20 Advanced Game Operation Map.

Game Design Document (GDD)

Depending on the literature, trials, and game fiction studies, the game design document was prepared before creating the application.

Table 4.1 Game Design Document**.**

Game Title	**GameArch**	
Game Aim	Enhance students' learning experiences in virtual environments. Measure the impact of the game on students' design processes. Provide foundational architectural knowledge through gameplay. Stimulate curiosity and encourage further research in architectural studies.	
Game Overview	**Genre:** Educational Game **Platform:** PC (Windows) **Target Audience:** Architecture students	**Game Perspective:** First-person **Art Style:** Low-poly, Stylized (similar to real-world references) **Game Engine:** Unity 3D
Other Characters	**NPCs:** Virtual mentor who provide information and challenges at different levels.	
Physical Features	Similar to the real world (gravity, dimensions, proportions)	
Game Elements	**Levels:** Urban, Town, Forest, and River Environments with specific architectural challenges. **Flashcards:** Information on architectural artifacts, landmarks, and structural systems. **Stages (Mini-Games):** Time-based mini-games (labyrinth, matching, and party games).	
Game Flow	**Level I: Urban Environment** - Focus on urban dynamics, find the exit on time. - Embedded knowledge: Urban built environment, climate data, and transportation. **Flashcard I & Stage I: Architectural Artifacts** - Learn about known architectural artifacts through visual cards. - Reinforce knowledge through gameplay. **Level II: Town Environment** - Focus on the town's dynamics. - Embedded knowledge: Town built and natural environment, socio-cultural structures.	**Flashcard II & Stage II: Pavilions** - Learn about pavilion buildings. - Reinforce knowledge through gameplay. **Level III: Forest Environment** - Focus on forest dynamics. - Embedded knowledge: Forest natural environment. **Flashcard III & Stage III: Structural Systems** - Learn about structural systems. - Reinforce knowledge through gameplay. **Level IV: River Environment** - Focus on river dynamics. - Embedded knowledge: River environment. Coastal and natural landscapes.

Table 4.1 Game Design Document **(continued)**

Game Mechanics	Core Gameplay Loop: **Navigate environments, complete tasks requiring knowledge.** Controls: **- Keyboard and mouse for navigation and interaction.** **- WASD keys for movement.** **- Mouse for camera control and interaction with objects.** Objectives: **Complete levels by solving problems, collecting items, avoiding obstacles on time.** Rules: **- Complete levels within a given time.** **- Lose health on collision with vehicles or living beings; restore health if health is depleted, wait if all health finishes.** **- Earn time by catching monster.** **- Review flashcards after each level before each stage.** **- Solve architectural questions related to flashcards and play mini-games to complete stages on time.**	
Game Flowchart	1. Main Menu: Access game and options. 2. Level Start: Levels (Urban, Town, Forest, River environments). 3. Level Exploration: Navigate environment, complete tasks. 4. Flashcard Review: Study flashcards. 5. Stages/Mini-Games: Engage in time-based challenges and interactive elements. 6. Assessment: Receive feedback and scores. 7. Exit	
User Interface	**Main Menu:** - Start Game - Continue/Exit	**In-Game HUD:** - Health Bar - Timer - Points - Objectives List
Production	- Unity 3D Game Engine - Asset Creation: Models, Textures (Blender3D, Unity 3D, Asset Store Downloads, Adobe Fresco) - Single Platform Game - Programming: Gameplay Mechanics, UI, C#	

4.2.1.3 Game Application

Depending on all these game concept designs, “GameArch produced. "GameArch" is an educational PC game designed to enhance architecture students' learning through virtual environments. Developed with Unity 3D, it features a first-person perspective and a low-poly, stylized art style. Players navigate levels like Urban, Town, Forest, and River, each with architectural challenges and embedded knowledge. The game uses flashcards to teach architectural concepts, and stages reinforce these concepts by mini-games. Core gameplay involves solving architectural tasks with keyboard and mouse controls (App-2).

4.3 Case: Enhancing Architectural Design Experience Through XR

The reviewed studies in Chapter 3, mainly focusing on the design experience using VR, AR, and MR tools, encompass a wide range of objectives and methodologies tailored to the needs and requirements of specific disciplines. These studies often explore the development and application of virtual and augmented reality environments, devices, and software, aiming to enhance various aspects of design education and practice. In architectural education, the usability of these technologies can vary significantly based on the educational design and field of study. Research in this area often investigates the integration of VR and AR components into the design process, examining their impact on spatial understanding, visualization, and collaboration among students. Integrating Extended Reality (XR) technologies into architectural design education significantly advances how design processes are taught and experienced. These technologies offer immersive and interactive environments that can enhance the understanding and creativity of architecture students, providing them with tools to visualize and manipulate designs in ways that conventional methods cannot (Chapter 3).

Various tools and software are commonly used to facilitate these immersive design experiences. Smartphones, headsets, tablets, laptops, and desktop computers are foundational platforms for VR, AR, and XR applications. Devices and headsets such as the HTC Vive Pro 2 (HTC Corporation, n.d.), Oculus Meta Quest 2 (Meta Platforms, n.d.), Microsoft Hololens 2 (Microsoft, n.d.), HP Reverb G2 (HP Development Company, L.P., n.d.), Valve Index (Valve Corporation, n.d.), and Lenovo Explorer (Lenovo, n.d.) offer immersive experiences that enhance the realism and interactivity of design visualizations.

Software tools like Revit, Maya 3D, 3ds Max (Autodesk, n.d.), Rhino (McNeel & Associates, n.d.), and SketchUp (Trimble Inc., n.d.) are widely used in architectural design to create detailed 3D models and environments. Collaborative design tools and real-time 3D creation platforms such as Mindesk VR (Mindesk, n.d.), Iris VR (IrisVR, n.d.), Fuzor (Kalloc Studios, n.d.), Varjo (Varjo Technologies, n.d.), VREX (VREX, n.d.), Arkio (Arkio, n.d.), Blender (Blender Foundation, n.d.), Unity (Unity Technologies, n.d.), and Unreal Engine (Epic Games, n.d.) provide powerful capabilities for designing, visualizing, and collaborating on architectural projects in virtual and augmented reality with these software tools.

In Chapter 3's systematic reviews, experimental studies have mostly been conducted to develop design applications in VR, AR, and MR environments; some have opted to utilize the software and collaboration tools mentioned above. However, creating the necessary infrastructure to meet the expected design quality requires significant time and intensive collaboration with different disciplines. Therefore, in this case study chapter, the chosen design platform was sought from existing platforms that offer a simple interface, ease of use, tools that do not hinder creative thinking, and the ability to quickly transition from abstract to concrete concepts, facilitating concept design production between the two.

By assessing various tools and environments, the study aims to pinpoint the most effective ways to incorporate immersive technologies into architectural education, thus fostering innovation and efficiency in the design process. In this case study, Arkio (Arkio, n.d.), a collaborative spatial design tool, offered a comprehensive design experience across multiple devices, including tablets, computers, and Meta Quest 2 (Meta Platforms, n.d.) headsets. Arkio enhances multi-design capabilities and provides an accessible platform that integrates seamlessly with other design software such as Revit (Autodesk, n.d.), Rhino (McNeel & Associates, n.d.), Unity (Unity Technologies, n.d.), and SketchUp (Trimble Inc., n.d.), enabling efficient workflow and collaboration across various platforms. Arkio supported the study by providing access to its Pro version, facilitating real-time collaboration and intuitive modeling in mixed-reality environments.

This chapter investigates the impact of XR technologies on architectural design education, focusing on their application in a case study involving students from the AGU School of Architecture.

This case study evaluates how XR tools, such as video games, tablets, and VR/AR headsets, influence architecture students' design experiences and outcomes. By embedding architectural knowledge within these tools and presenting it to students through game-based learning, the study seeks to determine the effectiveness of these innovative methods in teaching complex design concepts. Additionally, the study provides students with three different design problems, each set in a unique environment but similar in scale, concept, and difficulty, to assess their adaptability and performance across different design mediums.

The participant recruitment process was thorough, ensuring a well-matched and informed group of students with similar academic backgrounds.

The study collected extensive feedback on the students' experiences and perceptions of using XR technologies through pre-surveys, mid-surveys, post-surveys, and follow-up surveys. These surveys aimed to capture the initial familiarity with these technologies, their impacts during the design process, and the long-term effects on students' design methodologies.

In addition to survey data, the study also included output (design product) assessments and observations (observation chart) to evaluate objectively. This comprehensive approach allowed for a detailed analysis of the benefits and challenges of XR's impact on architectural education.

Overall, this chapter aims to provide insights into the transformative potential of XR technologies in enhancing architectural design education. By examining the strengths and weaknesses, the study seeks to establish a foundation for future modeling and integration of XR technologies in design studios, ultimately contributing to developing more interactive, innovative, and effective educational methodologies in architecture.

Participant Recruitment, Announcement, Selecting Criteria from Voluntary Students, Online Information Meeting

The Case Study documents were sent to the AGU ethical committee for Ethical evaluation. After the Ethical Committee Approved (App-3.1), recruitment for this study commenced with an email sent to all AGU Architecture students through the Department Head (App-3.3). Interested students voluntarily contacted the researcher to indicate their interest.

The selection process focused on their achievements in Architectural Design Studio Courses. Limited 2nd, 3rd, and 4th-year students were selected based on the selection criteria of their latest design studio grades.

Thirteen students initially volunteered to participate. Subsequently, a detailed briefing session was held via Zoom, during which the researcher presented the study's scope and experimental procedures. Following this meeting, two students decided to withdraw from the study.

For those continuing, the informed consent form (App-3.2) was distributed through a link provided in an email. The students who consented participated in the study by completing and submitting the consent form electronically (App-4.1).

This recruitment and consent process was instrumental in forming a well-informed and well-matched participant group, essential for ensuring the study's reliability and consistency (Figure 4.21).

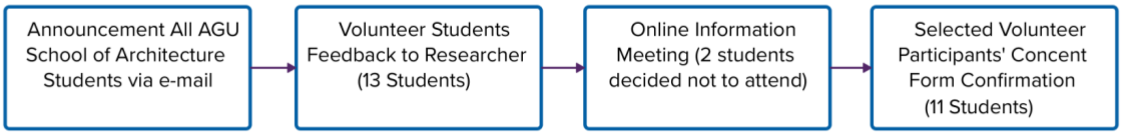


Figure 4.21 Case Study Preparation Process.

In this case, the students are coded as "ST." ST-1, ST-2, ST-3, ST-4, ST-5, ST-6 are 2nd year students, ST-7, ST-8, ST-9 are 3rd year students, and ST-10 and ST-11 are 4th year students.

Process

Three different design problems for each experience provided specific, consistent challenges for the students to address using conventional studios, screens (VR/AR), and VR headsets, allowing for a direct comparison of performance and experiences across different design environments (Figure 4.22).

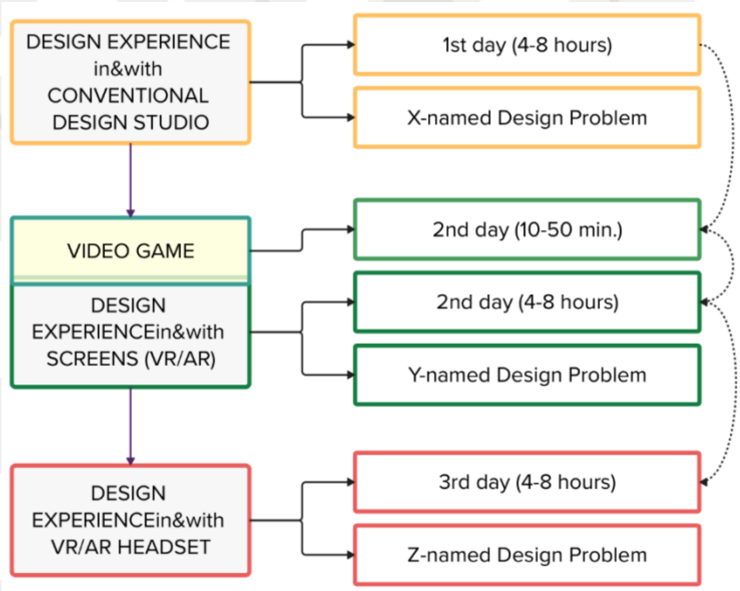


Figure 4.22 Case Study Process Scheme.

Design problems are created on similar scales and with simple limits to make them a constant parameter for the case.

- *X-named design problem: Design a study hub for students. (max. Volume: 9 m3, site: near BA Conference Hall, AGU Campus)*
- *Y-named design problem: Design a meeting hub for students. (max. Volume: 9 m3, site: behind BA02, AGU Campus)*

- *Z-named design problem: Design a research hub for students. (max. Volume: 9 m3, site: near BA02, AGU Campus)*

  1st day (4-8 hours): Before beginning the design, students were sent pre-survey questions and were asked to complete them. Then students were reminded that they would complete three different designs, each requiring 4-8 hours to complete. They were informed that no critiques would be given during the design process. Additionally, they were reminded about the tools, environments, and surveys they would use throughout the process and that they could withdraw from the study anytime. Then, the students were asked individually to design X-named design problems using a conventional design studio environment and tools. The design problem was explained to the students, and they were informed that they were free to use any tools they conventionally use in the studio.

  Each student experienced conventional design studio space and tools on their own first day, VR with game playing, VR/AR environment with screens on their own second day, and VR/AR environment with VR/AR headset on their own third day. The reason for including the term "VR/AR" in this study is that the devices and platforms allow students to use both Virtual Reality and Augmented Reality. Students can engage with both environments or opt for just one based on their preferences.

  (environment: BA01, AGU Campus) (Figure 4.23).

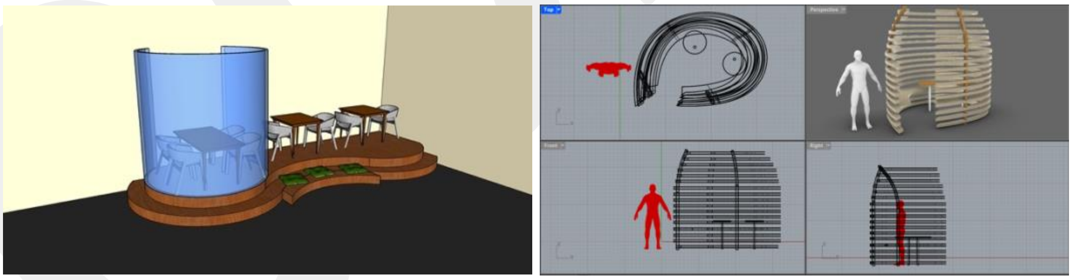


Figure 4.23 ST-7 and ST-3 Designs in the Conventional Design Studio.

2nd day (10-50 min.): Students were asked to play the GameArch, installed on laptops. They were informed that there was no time limit and that they could stop playing if they did not wish to complete the game (meeting place: BA01, AGU) (Figure 4.24).

Figure 4.24 ST-10 and ST-8 Game Scores.

2nd day (4-5 hours): Students were briefed on the Y-named design problem and briefly introduced to Arkio, the platform they would use for designing. They were also instructed on utilizing VR, AR, or both while designing in Arkio and with the tablets. Students learned to use this platform either by watching the tutorials available within it or through trial and error, using their own tablets or tablets provided by the researcher. Touch pens with tablets were permitted. After this, they began the design process (meeting place: BA01, AGU) (Figure 4.25). At the end of the second day, students were sent the mid-survey and asked to complete it.

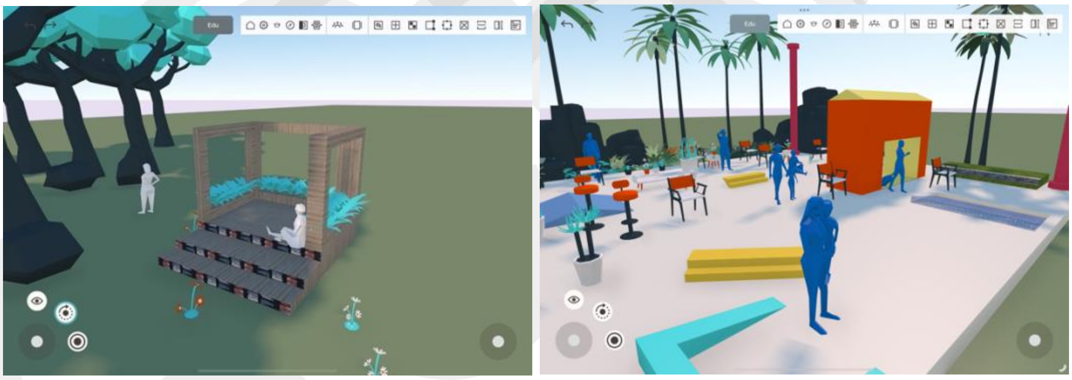


Figure 4.25 ST-6 and ST-9 designs in VR/AR with the screen.

3rd day (4-8 hours): Students were introduced to the Z-named design problem on the third day. The researcher provided a brief overview of how to use the VR/AR headsets and how to utilize the VR/AR features. Before starting the design process, students were given free time to explore the new environment by playing games or using the Arkio platform with headsets. They were encouraged to begin their design process once they felt ready. At the end of the third day, students were sent the post-survey questions and were asked to complete them (meeting place: BA01, AGU) (Figure 4.26).

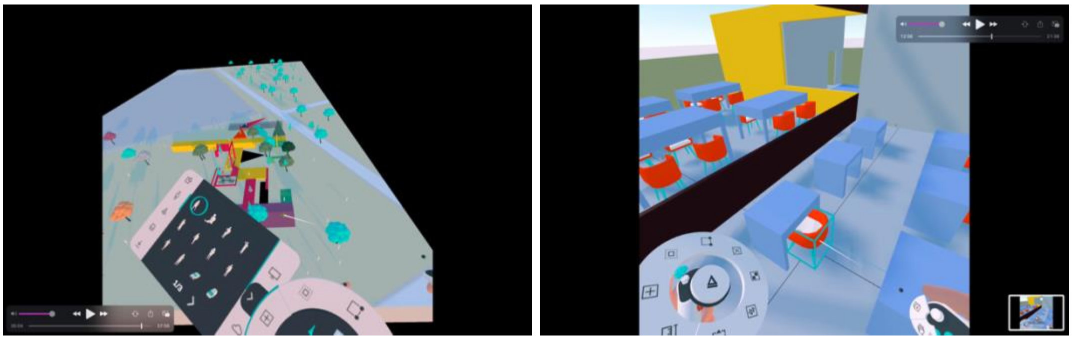


Figure 4.26 ST-8 and ST-7 designs in VR/AR with VR/AR headset.

4.4 Findings

The findings consolidate the insights acquired through surveys, output assessments, and observations to provide a comprehensive analysis of the impact of Extended Reality (XR) technologies on architectural design education derived from the case study. To discuss the impact from all perspectives with findings, first, each data collection's results are presented with a holistic evaluation of all students, and then each student's results are presented experience by experience.

4.4.1 Survey Results

For the analysis of the surveys (which include open-ended, dichotomous, and rating scale questions) data, a combination of thematic and quantitative analysis techniques was applied, utilizing MAXQDA (VERBI Software, 2022) for qualitative data coding and theme identification. Microsoft Excel (Microsoft Corporation, 2021) was utilized to analyze quantitative data. Then, both qualitative and quantitative findings were synthesized.

To effectively evaluate the impact of Extended Reality (XR) technologies in architectural design education, a planned survey methodology is implemented at various stages of the learning process. This strategy is detailed below, illustrating how each survey phase contributes to a comprehensive understanding of student interactions with XR technologies.

The Pre-Survey aims to understand the students' familiarity, perceptions, and expectations regarding XR technologies. This survey, administered before the design experience process begins, uses a combination of open-ended, dichotomous (yes/no), and rating scale questions to gather initial data.

Following the initial survey, the Mid-Survey is conducted after the participants have experienced the design process using VR/AR screens. This survey aims to collect insights into participants' experiences with a video game used as an educational tool in architectural design. It similarly employs open-ended, dichotomous, and rating scale questions to capture the immediate impacts of XR technology usage in educational settings.

The Post-Survey is conducted after all design experiences are completed. This survey aims to gather detailed participant feedback on their overall experiences and perceptions after completing a series of design tasks using different environments, including conventional studios, screens, and VR headsets. It includes open-ended, multiple choice, and rating scale questions to assess a comprehensive range of factors influencing the learning experience.

Finally, the Follow-Up Survey is carried out one week after the case study to capture longer-term effects and reflections from the participants. This survey, featuring open-ended and rating scale questions, helps identify any sustained impacts or changes in perceptions that may have developed since completing the design tasks (Figure 4.27).

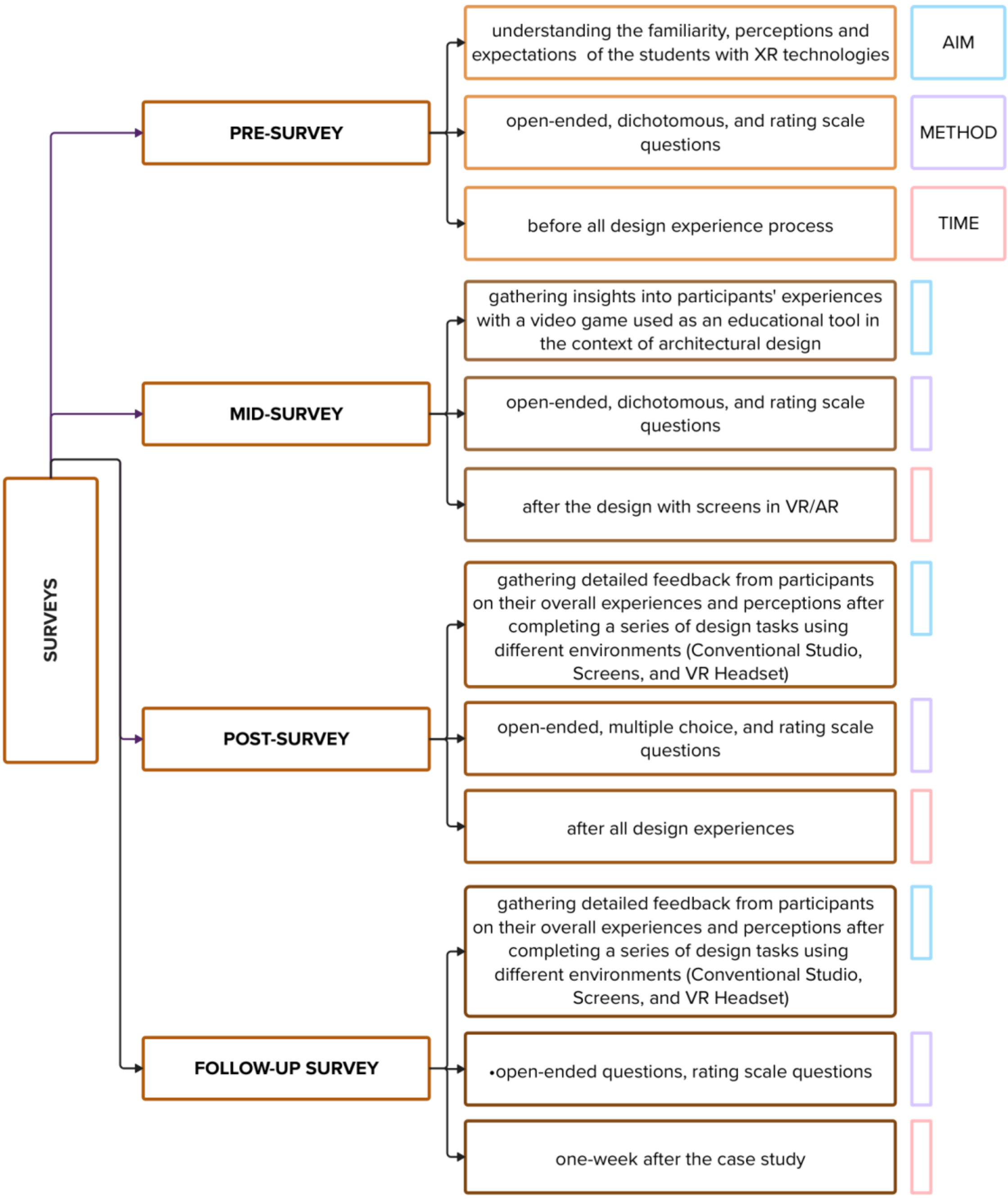


Figure 4.27 Surveys and their aim, method, and time.

The research is organized under four themes:

- XR (VR or/and AR) Familiarity and Baseline Assessment (Pre-Survey)
- XR (VR or/and) Implementation Feedback (Mid-Survey)
- XR (VR or/and) Impact Feedback (Post-Survey)
- Long-Term XR (VR or/and) Impact Evaluation (Follow-up Survey)

To make a more meaningful synthesis with the themes generated from the survey results, all survey responses were also evaluated separately for each theme.

4.4.1.1 Pre-Survey Results (XR (VR or/and AR) Familiarity and Baseline Assessment) (App-4.2)

The assessment of participants' familiarity with Extended Reality (XR) Technologies and Virtual Reality (VR) Technologies revealed varying levels of familiarity.

- In this category of XR technologies, 72.73% of participants were "Not Familiar at All," while 27.27% were "Slightly Familiar." Comments such as "Not Familiar at all" ST-10 highlighted the general unfamiliarity among participants, although some, like ST-9, mentioned being "Slightly Familiar."
- Regarding VR technologies, 54.55% of participants were "Not Familiar at All," and 45.45% were "Slightly Familiar." For instance, ST-7 stated they were "Not Familiar at all," while ST-11 reported being "Slightly Familiar."
- In contrast, evaluations of conventional design studio tools showed greater familiarity. Participants such as ST-9 expressed being " Extremely Familiar" with these tools, ST-10 noted being "Slightly Familiar," and a minority, like ST-11, indicated "Not familiar at all."

These baseline assessments are crucial for understanding the participants' starting points and evaluating the impact of introducing XR technologies in the design process. They provide a foundation for measuring changes in familiarity and perception post-intervention.

- The assessments of participants' expectations on using extended reality (XR) technology in the design process were coded as Contributing to an Individual's Design Development (%50), Facilitating the Process (%43), and Minimizing Errors (%7).
    - Participants in the Expectations have predominantly expressed views on the "Contributing to Individual's Design Development" code. Participant coded as ST-2 has mentioned the following:

      "I believe that using new techniques while designing a space will give me new visions and ideas, so using XR technologies will give me new ideas." (ST-2)
    - Participants have also mentioned the "Facilitating the Process" code. Participant coded as ST-8 has mentioned the following:

"The chance to experience many details of the design at the same time, more easily and in a shorter time, and to be able to explain the design to others more easily." (ST-8)

- Participants discussed 'Minimizing Errors.' A participant with code ST-5 mentioned the following regarding the topic.

  "I expect to be able to visualize designs more realistically and to detect errors more easily." (ST-5)

- Regarding the students' expectations of VR technologies in the design process, participants have expressed intensive views regarding the code Contributing to Individual Design Development (%54). The participant with code ST-2 mentioned the following regarding the topic:

  "This will be the first time for me to use VR while designing. I think it will helpful for me to understand the space more efficiently." (ST-2)

  - Participants also provided feedback regarding the augmenting reality (%31) code. A participant with code ST-6 mentioned the following regarding the topic.

    "to increase reality, virtual reality is so important, especially for the design process in terms of creating idea part and to build in real. To improve understanding of the process it can be beneficial." (ST-6)

  - Participants have also provided feedback regarding the Minimizing Errors (%15) code. ST-5 participant mentioned the following regarding the topic.

    "I expect to be able to visualize designs more realistically and to detect errors more easily." (ST-5)

The theme "XR (VR or/and AR) Familiarity and Baseline Assessment" has been studied according to participants. Accordingly, participants' opinions have concentrated on the codes "Easy Access to Personal Technological Devices," "Not Familiar at All," and "Contributing to Individual's Design Development."

4.4.1.2 Mid-Survey Results (XR (VR or/and AR) + Video Game Implementation Feedback) (App-4.3)

The second theme of the research, "XR (VR or/and AR) Implementation Feedback," is displayed in the hierarchical code sections. The theme "XR (VR or/and AR) Implementation Feedback" has been analyzed hierarchically under three different categories: "Evaluations Regarding Video Games in the Design Process," "The

Advantages of Incorporating Video Games in the Design Process," and "Evaluations on the Integration of Video Games in Architectural Education."

- **Evaluations Regarding Video Games in the Design Process**

Five codes were created in the Evaluations Regarding Video Games category of the Design Process category. These include engagement with Video Games (%29), creating a Shift in Perspective (%26), Influencing an Individual's Design Decisions (%19), not thinking it will contribute (%19), and Developing an Individual's Vision (%16).

- Participants expressed intense opinions about Engagement with Video Games. Regarding the subject, participants coded ST-3 mentioned the following:

  "Very Engaged" (ST-3)

- Participants also expressed their opinions on "Creating a Shift in Perspective." Participants coded with ST-2 mentioned the following on this topic:

  "I think video games would be a good method in the field of architecture. After all, every game has a world that is sometimes realistic and sometimes utopian, and I think this can be used to develop creativity and identify problems in different situations." (ST-2)

- Participants also expressed their opinions on " Influencing an Individual's Design Decisions." Participants coded with ST-6 mentioned the following on this topic:

  "Getting used to the environment with a video game before starting the design process allowed me to have much more efficient design process. In order to use the technological environment and control perspectives." (ST-6)

- Participants also expressed their opinions about the 'Not Thinking It Will Contribute' category. Regarding the subject, participants coded ST-7 mentioned the following:

  "I think that wandering around the labyrinth independently of the city makes it difficult for us to perceive the city. Our only goal while playing the game was to enter the maze and complete the task, so I don't think our assigned tasks have the ability to influence the design process."

- Participants also expressed their opinions about Developing Individual's Vision. Regarding the subject, participants coded ST-4 mentioned the following:

  "Being able to see some important architectural structures simultaneously during the design process contributed to broadening my horizons and gaining inspiration."

- **The Advantages of Incorporating Video Games in the Design Process**

Three codes were also created under the category of The Advantages of Incorporating Video Games in the Design Process. These contribute to an Individual's Design Knowledge and Experience (%71), Making Learning Enjoyable (%23), and Ensuring Accurate Problem Identification (%6).

- Participants commented extensively on Contributing to Individual's Design Knowledge and Experience in this category. Regarding the subject, participants coded ST-7 mentioned the following:

  "This game helped me understand once again the difficulty of walking on a rough road and the importance of pedestrian paths." (ST-7)

- Participants also expressed their opinions about The Advantages of Incorporating Video Games in the Design Process code. Participants coded ST-10 mentioned the following regarding the subject:

  "Video games offer a unique perspective in this regard, emphasizing a more informal approach to education rather than alternative educational methods or conventional methods. In fact, they can create a fun, competitive environment that enhances learning." (ST-10)

- Participants expressed their opinions about Ensuring Accurate Problem Identification. Participants coded ST-10 mentioned the following regarding the subject:

  "While quizzes and tests take us only so far in understanding who built what structures with what materials or structural systems, games do provide a tutorial field where we can explore. These games serve as an entertaining and educational platform. They offer a space beyond traditional assessments, allowing us to engage in hands-on exploration and learning. (ST-10)

- **Evaluations on the Integration of Video Games in Architectural Education**

  Two codes were created in the Evaluations on the Integration of Video Games in the Architectural Education category: Implementing Improvements (%81) and the Necessity of Integration into the Education System (%19).

  - Participants extensively mentioned the Implementing Improvements code. Regarding the subject, participants coded ST-11 mentioned the following;

    "If a more realistic and comfortable working environment is created in the game, organic shapes and a more realistic perception of space and structure, the more efficient the designs can be." (ST-11)

  - Participants also mentioned the code The Necessity of Integration into the Education System. Regarding the subject, participants coded ST-2 mentioned the following;

    "I think video games would be a good method in the field of architecture. After all, every game has a world that is sometimes realistic and sometimes utopian, and I think this can be used to develop creativity and identify problems in different situations." (ST-2).

The theme of XR (VR or/and) AR Implementation Feedback was examined according to the participants. Participants' opinions focused on implementing improvements, contributing to individuals' design knowledge and experience, and engaging with video game codes.

4.4.1.3 Post-Survey Results (XR (VR or/and AR) Impact Reflection) (App-4.4)

The "XR (VR or/and AR) Impact Reflection" hierarchical code sections model. The theme of Challenges Encountered During Design Experiences was examined under three categories: Challenges Encountered During Design Experiences, Contributions of Design Experiences, and Assessments Regarding the Preferred Study Environment in the Future.

- **Challenges Encountered During Design Experiences**

  Nine codes were created under the Challenges Encountered During Design Experiences category. These are Lack of Knowledge of How to Use the System/Application (%33), Inadequacy of Software (%27), Prejudice Against the System/Technology (%12), The Lack of Ergonomics in VR Headset (%9), Integration Issue (%6), Difficulty Understanding Mobility (%3), The Dependency of Usage on Skill (%3), The Limitation of Personal Design Development by

Conventional Design Techniques (%3), Studies Conducted on Screens (%3) (Tablets).

- Participants commented extensively on the Lack of Knowledge on How to Use the System/Application. Regarding the subject, participants coded ST-3 mentioned the following:

  "The difficulty in the first stage was that I could not feel the design and details well enough. In the second stage, I was not able to perform commands such as rotating and turning on the iPad. At the last stage, the diffuculty was not knowing what to do due to using VR glasses and controllers for the first time." (ST-3)

- Participants also expressed their opinions about the Inadequacy of Software. Regarding the subject, participants coded ST-2 mentioned the following:

  "It is now clear that technology has an important place in our lives and provides convenience in many professional fields and I think architecture is one of the fields where technology can be used most efficiently. For this experience, I do not think video game and application we use is enough." (ST-2)

- Participants also expressed their opinions about Prejudice Against the System/Technology. Regarding the subject, participants coded ST-6 mentioned the following:

  "I was scared a little bit actually in order not to manage the process. Because ı was a lover for free hand drawing. I'm not be able to produce products in pc or technological environments. But after the study, Just in a hour ı really get used to control the commands." (ST-6)

- Participants expressed their opinions about The Lack of Ergonomics in VR Headsets. Regarding the subject, participants coded ST-6 mentioned the following:

  "to be honest, I was just familiar with convential studio before attending this activity. With 0 knowledge then just a few day practice, I thought vr headset can adapte to our design process. But actually for feeling comfort, screens maybe can better choice. Because vr headset wasnot ergonomic especially for long hours." (ST-6)

- Participants expressed their opinions about the Integration Issue. Regarding the subject, participants coded ST-1 mentioned the following:

“Each design environment offers unique advantages and challenges for collaboration. Physical environments excel in immediate feedback and spontaneous ideation but are limited by geographical constraints. Virtual environments enable asynchronous collaboration and easy file sharing but may lack the richness of face-to-face interaction. Hybrid environments strive to combine the best of both worlds but require careful management to ensure seamless integration and inclusivity.” (ST-1)

- Participants also expressed their opinions about Difficulty Understanding Mobility. Regarding the subject, participants coded ST-8 mentioned the following:

  “Understanding the tools, we used in each design environments. Before starting the design with Vr or Ar people should have experiences with the devices. Otherwise it will limit the design skills.” (ST-8)

- Participants expressed their opinions about The Dependency of Usage on Skill. Regarding the subject, participants coded ST-3 mentioned the following:

  “The first stage felt normal because it was a process I was used to. The second and final stages were an interesting experience. It allowed me to discover design skills I didn't have.” (ST-3)

- Participants expressed their opinions about The Limitations of Personal Design Development by Conventional Design Techniques. Regarding the subject, participants coded ST-2 mentioned the following:

  “Using pencil and paper prevents creativity from taking shape according to the limits of any application.” (ST-2)

- Participants expressed their opinions about Studies Conducted on Screens (Tablets). Participants coded ST-10 mentioned the following regarding the subject:

  “Working on a design on a tablet was the most challenging and time-consuming aspect for me” (ST-10)

- **Contributions of Design Experiences**

Six codes were created under the Contributions of Design Experiences category. These are Contributing to Personal Design Development (%29), Satisfaction with Design Experiences (%28), Facilitating the Design Process by VR Headset (%20), Approaching the Current Situation from a Different Perspective (%11), The

Contribution of Extended Reality (XR) Technologies to Design Development (%8), and evaluating that the Conventional Method is More It is effective (%4).

- They expressed intense opinions about Contributing to Personal Design Development. Participants with code ST-2 mentioned the following regarding the subject:

  "I think it has evolved as I think each method will be more effective in different areas of design." (ST-2)
- They expressed their opinions on Satisfaction with Design Experiences. Participants with code ST-3 mentioned the following regarding the subject:

  "I would like to use the VR headset again in the design processes. The chance to experience the scale of the design on a true scale was very impressive. I will also include the opportunity to quickly design from an iPad into my design process." (ST-3)
- They commented on The Facilitation of the Design Process by VR Headset. Participants coded ST-4 mentioned the following regarding the subject:

  "I prefer a VR Headset. I think it is more practical and comfortable." (ST-4)
- They also expressed their opinions on Approaching the Current Situation from A Different Perspective. Participants with code ST-3 mentioned the following regarding the subject:

  "Using VR technology scared me a little at first. Because I don't know how to use devices. I was wondering how much of an impact it could have. But after experiencing it, my ideas changed and I found it much more useful." (ST-3)
- They also expressed their opinions about The Contribution of Extended Reality (XR) Technologies to Design Development. Participants with code ST-10 mentioned the following regarding the subject:

  "Extremely." (ST-10)
- They also expressed their opinions by Evaluating that the Conventional Method is More Effective. Regarding the subject, participants coded ST-6 mentioned the following:

  "I still feel more comfortable in conventional studio, but trying those process is also getting easier for screens. But normally I do not have the chance to reach VR glasses." (ST-6)

- **Assessments Regarding the Preferred Study Environment in the Future**

Two codes were created under the category Assessments Regarding the Preferred Study Environment in the Future: Preferring to Study in a Virtual Environment with VR Headset (%50) and Integration of All Environments/Methods (%50).

  - Students expressed their opinions extensively about Preferring to Study in a Virtual Environment with VR Headset. Regarding the subject, participants with the code ST-10 mentioned the following:

    "I believe VR would probably be the better option. With advancing technologies, experiencing a space firsthand through VR seems to be the most effective way. If we consider that our designs are essentially a form of marketing, we can say that experience is crucial for marketing. Additionally, considering there is also rendering involved in VR, I think it will become a commonly used tool in the future. "(ST-10)

  - They also expressed their opinions about the Integration of All Environments/Methods. Regarding the subject, participants with the code ST-11 mentioned the following:

    "They should all be used together. They all benefit the process." (ST-11)

The theme of XR (VR or/and) AR Implementation Feedback was examined according to the participants. Accordingly, the participants' opinions focused on contributing to personal design development, satisfaction with design experiences, and facilitating the design process by VR headset codes.

4.4.1.4 Follow-Up Survey Results (Long-Term XR (VR or/and AR) Impact Evaluation) (App-4.5)

The hierarchical code section model of "Long-Term XR (VR or/and AR) Impact Evaluation" is the Effects of Conducted Design Experiences and Recommendations Advancing Study.

- **Effects of Conducted Design Experiences**
  - They expressed intense opinions about Improving Design Skills. Participants coded ST-9 mentioned the following regarding the subject:

    "I am planning to insert VR headset into my design development to test it out. "(ST-9)

- They also expressed their opinions about Incorporating New Technologies into the Future. Regarding the subject, participants with code ST-3 mentioned the following:

  "In addition to teaching something different experientially, XR technologies showed that the traditional design process will move to more technological dimensions." (ST-3)
- They also expressed their opinions about Using Creative Methods. Participants with code ST-3 mentioned the following regarding the subject:

  "The conventional studio started to feel more boring in the creation process. When compared, the other two methods seem more practical and innovative." (ST-3)
- They also expressed their opinions about Developing Imagination. Participants coded ST-5 mentioned the following regarding the subject:

  "I felt free while designing because our dreams are usually limited to what we see, but I think we can be freer with XR technology." (ST-5)
- They also expressed their opinions about Thinking Application as Inefficient. Participants with code ST-2 mentioned the following regarding the subject:

  "While screen and VR are nice experiences, I don't think I've experienced enough to have a long-lasting impact on my design skills and perspective." (ST-2)
- They also expressed their opinions about; In the future, Wish to Participate in Similar Experiences in the Effects of Conducted Design Experiences category. Regarding the subject, participants with code ST-3 mentioned the following:

  "It hasn't changed completely, but I have integrated the methods we used in this process into myself and plan to work with and again." (ST-3)
- They also expressed their opinions about Utilizing Acquired Experiences in Other. Regarding the subject, all participants mentioned the following:

  "Yes." (ST-4)

- **Recommendations for Advancing the Study**

The Recommendations for Advancing the Study category includes two codes: Enhancing/Diversifying the Application and Increasing the Number of Virtual Reality Applications.

- Participants expressed intense opinions about Enhancing/Diversifying the Application in the Recommendations for Advancing the Study category. Regarding the subject, participant coded ST-8 mentioned the following;

  "Experiencing all the processes was a very helpful point. I think this helps us understand more easily. I think that when the contents of these experiences are studied and organized, they can be more open to new skills and develop." (ST-8)
- In the Recommendations for Advancing the Study category, participants also expressed their opinions about Increasing the Number of Virtual Reality Applications. Regarding the subject, participant coded ST-5 mentioned the following;

  "The application needs to improve; its design was limiting." (ST-5)

4.4.1.5 Overall Survey Results

The pre-survey insights revealed that most participants were limited to unfamiliar with XR technologies before the study, although they were mostly familiar with conventional design studio tools. Participants expected XR to enhance visualization, improve their understanding of spatial relationships, and assist in detecting design errors.

The mid-survey insights indicated that engagement levels with the video game related to architectural education varied, with most participants being moderately engaged. Participants noted that the video games helped them understand architectural concepts and design environments to a moderate extent.

The post-survey insights revealed that participants were overall satisfied with the different design experiences, including the Conventional Studio, Screens, and VR Headsets. Common challenges included navigating and designing on screens/tablets, initial difficulties with VR tools, and issues with integrating designs across different environments. Many participants found VR headsets to be the most conducive to their design process due to their ability to visualize designs in a realistic, 3D environment. However, some preferred conventional methods for the initial stages and VR for final visualization. Integrating XR technologies significantly enhanced participants' ability to innovate in the design process, and shared virtual environments improved collaboration.

The follow-up survey insights revealed that one week later, participants felt that while their fundamental design skills hadn't drastically changed, their approach to integrating new technologies in design had evolved. They wanted to use XR more frequently in their workflows.

The insights and skills gained from the study had begun to influence other design projects and coursework, though the extent varied among participants. Participants' preferences for specific design environments remained fairly consistent, with many strongly preferring VR headsets and combining conventional and digital methods. They suggested that XR tools need to be more ergonomic and intuitive and recommended improving the flexibility and capabilities of these tools to support organic and complex designs better. Many participants expressed interest in participating in future studies exploring the intersection of architectural design and emerging technologies, recommending that such studies be conducted over longer periods to better assess the impact of these technologies on design education.

This summary captures the key insights and feedback from all eleven participants across the various phases of the study, providing a comprehensive overview of their experiences and perceptions regarding the integration of XR technologies in architectural design.

The study concluded that integrating XR’s impact on architectural design education is it significantly enhanced students' visualization, spatial understanding, and ability to innovate and collaborate. While most participants were initially unfamiliar with these technologies, they reported overall satisfaction with their experiences, especially with VR headsets, which they found most conducive to the design process due to the realistic 3D visualization. However, they also faced challenges with screens/tablets and the initial use of VR tools. Over the long term, participants expressed a desire to integrate these technologies more frequently in their workflows, indicating that their approach to design had evolved. They suggested improvements in the ergonomics and intuitiveness of XR tools and recommended longer studies to better assess their impact on design education. Figure 4.28 shows the distribution of participant statements according to intensity. Codes shown in larger font sizes indicate expressions used more intensively, while expressions in smaller font sizes indicate that codes are used less intensively.

Figure 4.28 Word Cloud.

The codes participants frequently mentioned together are shown on the Code Map (Figure 4.29). The lines are shown wider to reflect the relationship of the more frequently mentioned codes mentioned together.

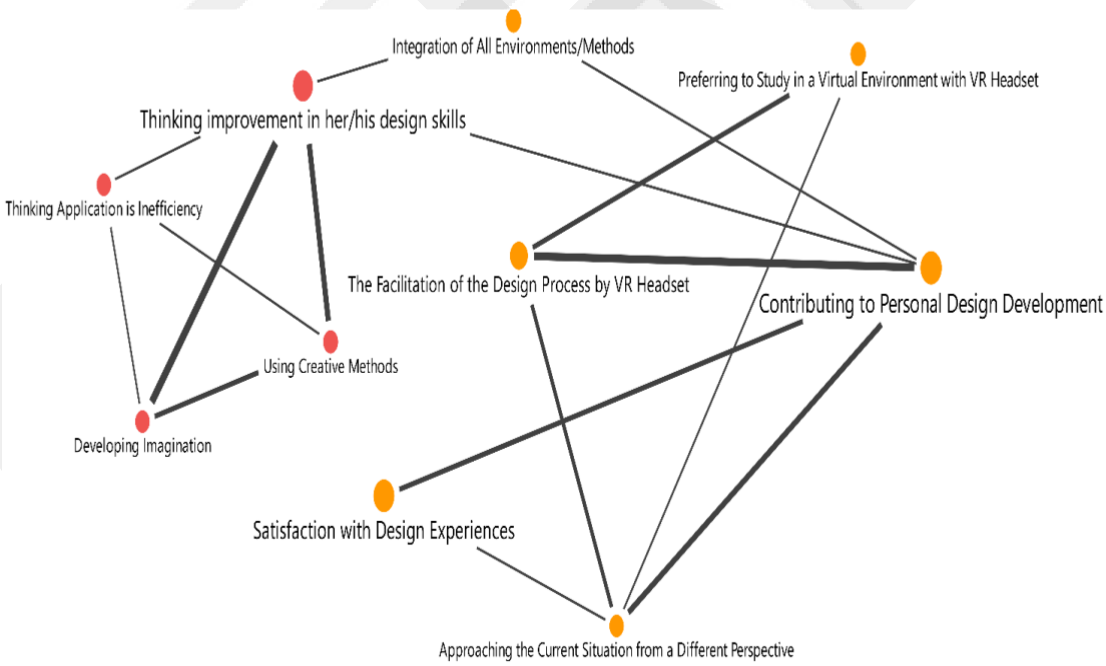


Figure 4.29 Code Map.

4.4.2 Output Assessments' Results (App-4.8)

The aim of the design product assessment method in this study was to objectively evaluate the quality and effectiveness of the design products created by students using three different tools and environments (Conventional Tools, Screens (VR/AR), and VR

Headsets (VR/AR)) by comparing. This method assessed creativity, functionality, spatial efficiency, technical proficiency, and representation, providing tangible evidence of students' skills and improvements. During the evaluation of these outputs, it was considered that the design process was carried out individually by the student and completed within a limited time frame. The impact of XR technologies on the quality of the final designs could be measured by analyzing the design products, identifying specific strengths and weaknesses in students' designs, and offering targeted feedback for further development. The output assessment was conducted using an analytical design evaluation rubric. Each student's design projects in three different environments were evaluated, and their grades were compared across these environments to derive the findings. For example, for Student ST-6, the conventional design experience was rated as Good overall, with very good creativity that showcases an innovative design approach. Functionality and spatial efficiency were both rated good, indicating a solid application of design principles, while technical proficiency was also good, and representation was fair, being reliable and clear. The design with screens (VR/AR) was rated as Very Good across all criteria, excelling in creativity, functionality, and spatial efficiency, reflecting an outstanding adaptation to digital environments. Technical proficiency and representation were also very good, demonstrating superior skill and clarity in the VR/AR mediums. Similarly, the design with the VR headset was rated as Very Good overall, with all criteria maintaining excellence, indicating a seamless transition to the immersive VR environment with high levels of creativity and technical mastery. Another example for student is ST-8 outputs; the conventional design output, which was rated as Very Good, demonstrates very good creativity, functionality, and spatial efficiency, along with good technical proficiency and representation, indicating a sophisticated understanding of design principles and clear visual communication. The design with screens (VR/AR) was also rated as Very Good overall, maintaining very good creativity and functionality, with spatial efficiency rated as good, slightly less effective than conventional tools. Technical proficiency was good, and representation was very good, showcasing high detail and clarity. The design with the VR headset was rated as Very Good, though creativity dropped to good. It maintained very good functionality and spatial efficiency, with good technical proficiency and representation, suggesting strong visual communication and functional design in an immersive environment.

The design products assessments across three environments—Conventional Tools, Screens (VR/AR), and VR Headsets—revealed key insights into student performance and adaptability to different design mediums. Subsequently, the Output outcomes of the students were consolidated and generalized when preparing the results.

Overall, students performed consistently well using conventional tools, frequently yielding good to excellent results in creativity, functionality, spatial efficiency, technical proficiency, and representation. Students seemed most comfortable and skilled with conventional design methods, often demonstrating high practicality and effective use of space. In contrast, designing with screens (VR/AR) presented mixed results. While some students adapted well to the digital environment, others struggled, particularly regarding functionality and spatial efficiency, indicating varying levels of comfort and proficiency with digital tools among students. The immersive environment of VR headsets brought varied results, with some students excelling and showcasing high levels of creativity and spatial efficiency, while others found it challenging to leverage VR's potential fully (Table 4.2).

Table 4.2 Comparison of Output’s Strength and Improvement Areas Based on Design Experiences.

Environment	Strengths	Areas Improvement
Conventional Tools	Functionality and Practicality: Many students scored excellently, reflecting well-thought-out and user-friendly designs. Spatial Efficiency: High scores indicate adept handling of space in design layouts.	Functionality and Practicality: Many students scored excellently, reflecting well-thought-out and user-friendly designs. Spatial Efficiency: High scores indicate adept handling of space in design layouts.
Screens (VR/AR)	Creativity: Many students maintained good creativity, showing an ability to adapt design concepts to digital tools. Representation: Generally good, indicating clear visualization of ideas in a digital format.	Functionality and Spatial Efficiency: Several students faced challenges, leading to lower scores compared to conventional tools. Technical Proficiency: Often fair, highlighting a need for improved VR/AR technicalities mastery.
VR Headset	Spatial Efficiency: Excellent scores for several students, reflecting effective use of immersive capabilities. Representation: Generally good, with some students achieving excellent clarity and detail in their VR designs.	Creativity: While good overall, some students did not fully exploit the innovative potential of VR. Technical Proficiency: Scores indicate a need for better technical handling of VR-specific features.

In conclusion, while students are strong in using conventional tools, there is a clear need for more education and practice in integrating digital tools and VR technologies. Students can achieve better outcomes in future design processes by enhancing their creativity and technical proficiency in these areas.

4.4.3 Observations' Results (App-4.7)

Observation charts were selected to evaluate students' interactions with XR technologies and their real-time performance. Each student's experience in the three different design environments was observed separately. Subsequently, the students' observation outcomes were consolidated and generalized when preparing the results.

Observation charts investigate student engagement, efficiency and challenges across three design environments: Conventional Design Studio, VR/AR with Screens, and VR/AR with VR/AR headsets.

As an example, ST-3 Experiences Observations as below:

- Conventional Design Studio (X-Named Design Problem): ST-3 was extremely engaged with the environment and tools, demonstrating excellent efficiency across all phases of the design process, from analysis to final presentation. No challenges were encountered in using tools, engaging with the environment, the design process, or motivation.
- Design in VR/AR with Screens (Y-Named Design Problem): ST-3 was extensively engaged, with good efficiency in all phases of the design process. Minor challenges were noted in using tools, engaging with the environment, the design process, and motivation.
- Design in VR/AR with VR Headset (Z-Named Design Problem): ST-3 was actively engaged, showing good efficiency in design improvement, final design, and presentation phases but moderate efficiency in analysis, synthesis, and concept studies. Minor challenges were experienced with tools, design process, and motivation, while moderate challenges were noted in engaging with the VR environment.

As another example ST-9 Experiences Observations as below:

- Conventional Design Studio (X-Named Design Problem): ST-9 was extensively engaged with the environment and tools, demonstrating excellent efficiency across all phases of the design process, from analysis to final presentation. No challenges were encountered in using tools, engaging with the environment, the design process, or motivation.

- Design in VR/AR with Screens (Y-Named Design Problem): ST-9 was actively engaged, showing excellent efficiency across all phases of the design process. Minor challenges were experienced in using tools, but there were no challenges in engaging with the environment, the design process, or motivation.
- Design in VR/AR with VR Headset (Z-Named Design Problem): ST-9 was extensively engaged, with moderate efficiency in the design, analysis, synthesis, and concept studies phases, and excellent efficiency in the final design and presentation phases. Minor challenges were experienced in using tools, engaging with the environment, and the design process, but there were no challenges in motivation.

These observation results were used to support the accuracy of findings from the student surveys, ensuring that the data was collected objectively and systematically.

These criteria—engagement, interaction, and efficiency—were chosen to compare XR technologies with conventional design studios, assess the impact of XR on students in design education, validate the accuracy of student survey findings and design product results, and offer valuable guidance for future studies (Table 4.3).

Table 4.3 Students' Design Process Comparision of Observations through Three Environments

Environment	Engagement and Interaction	Efficiency	Challenges
Conventional Design Studio	All students exhibited high levels of engagement and interaction with the conventional design studio environment and tools.	Students consistently demonstrated excellent efficiency in all design phases: design, analyzing, synthesis, concept, design improvement, final design, and presentation.	No significant challenges were reported in using tools, engaging with the environment, or maintaining motivation.
VR/AR with Screens	Students showed varying levels of engagement and interaction. Most were actively engaged, but a few had moderate engagement levels.	Efficiency levels varied: Some students demonstrated excellent efficiency in design, analyzing, synthesis, concept, design improvement, final design, and presentation phases. - Others showed good efficiency, with some phases like concept studies or design improvement being slightly less efficient.	Some students experienced minor challenges in using tools and engaging with the environment. Moderate challenges were noted in the design process and motivation for a few students.
VR/AR with VR Headset	Engagement and interaction levels varied more significantly compared to other environments. - Some students were extensively engaged, while others showed moderate levels of engagement.	Efficiency ranged from good to moderate: several students demonstrated extreme efficiency in most phases. - A few students showed good to moderate efficiency, particularly in the synthesis and concept studies phases.	Minor to moderate challenges were noted in using tools and engaging with the environment. Some students experienced minor motivational challenges.

Engagement was highest in the conventional design studio, while it varied in VR/AR environments, with VR headsets sometimes reducing engagement levels. Efficiency remained consistently high in the conventional studio and was good to excellent in VR/AR with screens, although slightly lower than in the conventional studio. In VR/AR with VR headsets, efficiency ranged from moderate to excellent, showing notable variability. Challenges were minimal in the conventional studio, but some arose in tool usage and engagement in VR/AR with screens. More challenges were encountered in VR/AR with VR headsets, particularly in maintaining motivation.

Integrating XR technologies (VR/AR with screens and VR headsets) offers new dimensions to architectural design experiences, enhancing efficiency in some aspects and introducing new challenges. While conventional design studios remain highly effective in engaging students and maintaining high efficiency, XR environments require adjustments in tool interaction and motivational strategies to achieve similar levels of engagement and efficiency.

4.5 Overall Results and Conclusion

This case study explored the impact of integrating XR (Extended Reality) and VR (Virtual Reality) technologies into architectural design education, focusing on how these tools influence students' design experiences, processes, and outcomes.

ST-1 Design Experiences:

Conventional Design Studio

ST-1 demonstrated a strong proficiency in the conventional design studio environment, showing excellent efficiency across all phases of the design process, from initial analysis to final presentation. The student was extremely engaged, interacting extensively with both the environment and the tools without encountering any significant challenges. The design product in this environment was rated as good overall, with particular strengths in functionality, practicality, and spatial efficiency, though design concept, creativity, representation and technical proficiency were noted as areas with room for improvement. This suggests that ST-1 is highly comfortable and adept with conventional design methods, effectively utilizing them to produce competent design solutions.

VR/AR with Screens

In the VR/AR environment with screens, ST-1's engagement and interaction remained active, though slightly less than in the conventional studio. The student's efficiency in the design phases was good, though not as strong as in the conventional setting. Minor challenges were noted in tool usage, environment engagement, and motivation, with moderate challenges in the design process and design. The design product in this environment was also rated as good, maintaining consistency in functionality but showing a slight drop in technical proficiency. The student expressed that the VR/AR technology was slightly challenging to adapt to, which aligns with the observed drop in efficiency and the need for better mastery of the tools.

VR/AR with VR Headset

The VR/AR environment with the VR headset presented a mixed experience for ST-1. The student remained actively engaged but faced moderate challenges, particularly in concept studies and tool usage. Despite these challenges, the design product was still rated as good, with the immersive nature of the headset contributing positively to spatial efficiency and practical functionality. However, creativity and technical proficiency did not significantly improve compared to the other environments. ST-1 recognized the potential of VR headsets in enhancing the design process but also noted a lack of creativity, suggesting a preference for integrating VR tools with conventional methods to maximize benefits.

Conclusion

ST-1's design experiences across the three environments indicate a clear comfort and efficiency with the conventional design studio, where the student excelled without encountering any significant challenges. In contrast, the VR/AR environments, particularly with the VR headset, posed moderate challenges, especially in adapting to new tools and maintaining creativity. Despite these challenges, the student's output remained consistently good, with functionality and spatial efficiency being strengths across all environments.

The surveys, output assessments, and observations support each other, reflecting the student's acknowledgment of challenges in adapting to new technologies while recognizing their potential. ST-1's preference for a hybrid approach, combining conventional methods with VR tools, aligns with the observation that while XR technologies offer innovative possibilities, they may benefit from being used with conventional design practices to realize their potential in architectural education fully.

ST-2 Design Experiences:

Conventional Design Studio

ST-2 demonstrated high engagement and efficiency within the conventional design studio environment. The student was extremely engaged, interacting extensively with both the environment and tools without encountering any challenges. ST-2 showed excellent efficiency across all phases of the design process, from initial analysis to final presentation. The design product in this environment was rated as good overall. Functionality, practicality, creativity, spatial efficiency, technical proficiency, and representation were all rated as good, indicating a solid and reliable approach to design, though with room for further innovation and refinement. This suggests that despite a lack of familiarity with conventional tools, ST-2 adapted well to the conventional studio environment and produced competent designs.

VR/AR with Screens

In the VR/AR environment with screens, ST-2's engagement was active but less pronounced compared to the conventional studio. The student encountered moderate challenges across various phases of the design process, particularly in the concept, design improvement, and presentation phases. The design product in this environment was rated as fair overall. While creativity remained good, there was a decline in functionality, spatial efficiency, and technical proficiency, all rated as fair. This reflects difficulties adapting to the digital environment and utilizing VR/AR tools effectively. ST-2 acknowledged the challenges in getting accustomed to the application, which aligns with the observed moderate efficiency and the need for better technical handling in this environment.

VR/AR with VR Headset

The VR/AR environment with the VR headset presented moderate engagement for ST-2. The student experienced moderate challenges in most aspects of the design process, including tool usage, environment interaction, and concept development. Despite these challenges, this environment's design product was still rated as fair, with improvements in functionality and spatial efficiency compared to the screen-based environment. Creativity was consistent with the screen environment, suggesting that while the VR headset provided some advantages, ST-2 still struggled to fully leverage the potential of VR technologies. The student's moderate interaction with the tools and environment indicates discomfort or unfamiliarity with the technology, which impacted the overall design process.

Conclusion

ST-2's experiences across the three design environments reveal a clear preference for and proficiency in the conventional design studio, where the student excelled in all phases of the design process without encountering any significant challenges. In contrast, both the screen-based VR/AR environment and the VR headset environment posed moderate challenges, particularly in adapting to the new tools and environments. The students' design products in these digital environments were less effective than in the conventional studio, with notable functionality and spatial efficiency drops.

The surveys, output assessments, and observations are consistent with each other, reflecting ST-2's acknowledgment of the difficulties in adapting to XR technologies and the challenges in maintaining creativity and efficiency in these new environments. ST-2's preference for a hybrid approach, combining conventional methods with XR technologies, suggests recognizing the potential benefits of these tools while acknowledging the need for further familiarity and comfort with the technology. The student's overall experience highlights the importance of integrating new technologies gradually and providing sufficient support to help students adapt and maximize their potential in architectural design.

ST-3 Design Experiences:

Conventional Design Studio

ST-3 demonstrated outstanding proficiency and engagement in the conventional design studio environment. The student was extremely engaged, interacting extensively with both the environment and tools. ST-3 displayed excellent efficiency across all phases of the design process, from analysis to final presentation. The design product in this environment was rated as very good overall, with high marks in creativity, functionality, spatial efficiency, technical proficiency, and representation. The absence of any challenges in this environment suggests that ST-3 is highly comfortable and skilled with conventional design methods, effectively using them to produce high-quality design solutions.

VR/AR with Screens

In the VR/AR environment with screens, ST-3 remained highly engaged, though slightly less so than in the conventional studio. The student demonstrated good efficiency in the design phases, though not as consistently excellent as in the conventional setting. Minor challenges were observed in using tools and engaging with the environment, which may have affected the design process slightly. Nevertheless, the design product in this environment was still rated as very good, maintaining high standards in creativity, functionality, spatial efficiency, technical proficiency, and representation. This suggests that ST-3 adapted well to the VR/AR environment with screens, although there was a slight dip in the overall ease of the process compared to the conventional studio.

VR/AR with VR Headset

The VR/AR environment with the VR headset posed more significant challenges for ST-3, especially in the initial stages. The student experienced moderate efficiency in analyzing and synthesizing studies and faced moderate challenges in engaging with the environment and using the tools. However, once ST-3 became accustomed to VR technology, efficiency improved, particularly in design improvement and final design studies. The design product in this environment was rated as very good overall, with all key aspects—including creativity, functionality, spatial efficiency, technical proficiency, and representation—deemed excellent. This indicates that while the VR headset environment initially presented challenges, ST-3 ultimately mastered the tools and produced highly effective and innovative designs.

Conclusion

ST-3's design experiences across the three environments reveal high adaptability and proficiency. The student excelled in the conventional design studio, where the design process was seamless, and the output was consistently excellent. The transition to digital environments, both with screens and VR headsets, introduced some initial challenges, particularly with the VR headset. However, ST-3 quickly overcame these challenges, demonstrating a strong capacity to adapt to new tools and environments while maintaining a high standard of design product.

The surveys, output assessments, and observations reflect ST-3’s ability to integrate XR technologies into the design process effectively. Despite the initial difficulties, ST-3’s preference for the VR headset environment underscores the potential of immersive technologies to enhance the design experience and output. The student’s experience highlights the value of embracing new technologies in architectural design, showing that with the right support and adaptation, these tools can significantly enrich the creative and practical aspects of the design process. ST-3’s journey suggests that integrating XR technologies into design education can lead to powerful and innovative design outcomes, even for students who initially find the technology challenging.

ST-4 Design Experience Analysis

Conventional Design Studio

ST-4's engagement and performance in the conventional design studio were moderate. The student demonstrated limited efficiency in most phases of the design process, particularly in concept development, design improvement, and final presentation. These limitations were reflected in the product's design, which was rated as fair overall. Creativity, functionality, and representation were all rated as fair, indicating basic competency but a lack of effective use of space. Technical proficiency and spatial efficiency were also highlighting a need for improvement. ST-4's motivation and interaction with the conventional studio environment were significantly challenged, aligning with the student's pre-survey statement that the conventional studio process is perceived as inefficient and incomplete.

VR/AR with Screens

In the VR/AR environment with screens, ST-4 showed improved performance and engagement compared to the conventional studio. The design product was rated as very good, with excellent creativity, suggesting that ST-4 could adapt well to digital tools and leverage them to enhance the design process. Functionality and spatial efficiency were also rated as very good, indicating a better understanding and application of spatial concepts in the VR/AR environment. However, technical proficiency and representation were rated as good, showing room for further development. While the student faced minor challenges with the tools and the environment, these were not significant enough to hinder overall performance. The student's positive response to the VR/AR environment reflects an ability to adapt to and benefit from digital tools, contrasting with the difficulties experienced in the conventional studio.

VR/AR with VR Headset

The VR/AR environment with the VR headset was where ST-4 showed active engagement and interaction, though the design product was still rated as fair overall. Creativity was rated as fair, indicating some improvement over the conventional studio, but spatial efficiency, technical proficiency, and representation remained fair. The immersive nature of the VR headset provided some advantages, but ST-4 faced moderate challenges in the design process, particularly in maintaining efficiency and motivation. Despite the challenges, the student preferred using the VR headset in future projects, finding it more practical and comfortable for design tasks.

Conclusion

ST-4's experiences across the three design environments reveal a clear preference for digital and immersive technologies over conventional design methods. The conventional design studio presented significant challenges in motivation and engagement, leading to fair outcomes in design performance. In contrast, the VR/AR screens allowed ST-4 to achieve better design outcomes, with good to excellent creativity and spatial efficiency ratings. While presenting some challenges, the VR headset environment was still preferred by ST-4 for its practicality and comfort, indicating a potential for further growth in this area with additional practice and familiarity.

The surveys, output assessments, and observations consistently show that ST-4 experienced varying success and comfort levels across different environments. The student's positive reception of XR technologies, particularly the VR headset, suggests that ST-4 could significantly improve their design skills and outcomes in immersive environments with more exposure and training. The overall analysis highlights the importance of integrating digital tools and immersive technologies in architectural education, particularly for students who struggle with conventional methods.

ST-5 Design Experience Analysis

Conventional Design Studio

ST-5 demonstrated strong engagement and proficiency in the conventional design studio environment. The student interacted extensively with both the environment and tools, displaying excellent efficiency across all phases of the design process, from initial analysis to final presentation. The design product was rated as very good overall, with excellent functionality and spatial efficiency. Creativity and technical proficiency were rated good, indicating a solid, well-rounded approach. ST-5 faced no significant challenges in this environment, reflecting high comfort and familiarity with conventional design methods.

VR/AR with Screens

In the VR/AR environment with screens, ST-5 maintained good engagement, although moderate challenges were encountered during the design process. The design product was rated as fair overall. Creativity, functionality, and spatial efficiency dropped to fair, suggesting difficulties adapting to the VR/AR tools effectively. Technical proficiency and representation were rated as good, reflecting a consistent effort to adapt to the digital tools despite the challenges. The student expressed a need for more advanced tools to support the design process better, highlighting the limitations of the software used in this environment. Despite these challenges, ST-5 showed a willingness to engage with the digital tools, recognizing their potential to improve design visualization.

VR/AR with VR Headset

The VR/AR environment with the VR headset presented significant challenges for ST-5. While the student remained actively engaged, the design product was rated as fair, with moderate efficiency in most phases of the design process. Creativity was rated as good, but functionality, spatial efficiency, technical proficiency, and representation were all rated as fair, indicating struggles with the immersive environment. ST-5 faced moderate challenges with the tools and the design process, as well as significant challenges in adjusting to the VR environment. Despite these difficulties, ST-5 expressed a strong preference for the VR headset in future projects, particularly for its ability to assist with 3D visualization, which is a known challenge for the student in conventional settings.

Conclusion

ST-5's experiences across the three design environments highlight strengths and improvement areas. The student excelled in the conventional design studio, where the process was smooth, and the outcomes were consistently good. However, the transition to digital and immersive environments introduced challenges, particularly with the VR headset, where the limitations of the software and tools became apparent.

The surveys, output assessments, and observations are consistent, reflecting ST-5's acknowledgment of the difficulties in adapting to new technologies and the need for more advanced tools to fully leverage the potential of XR environments. Despite these challenges, ST-5 recognizes the benefits of XR technologies, particularly in overcoming difficulties with 3D visualization, and expresses a strong interest in exploring these tools in future design projects.

ST-5's overall experience suggests that with improved tools and more practice, the student could significantly enhance their design outcomes in digital environments, particularly with VR headsets. The preference for XR technologies indicates a recognition of their potential to support and improve the architectural design process.

ST-6 Design Experience Analysis

Conventional Design Studio

ST-6 exhibited exceptional engagement and proficiency in the conventional design studio environment. The student interacted extensively with the environment and tools, demonstrating excellent efficiency across all phases of the design process, from analysis to final presentation. The design product was rated as good overall, with creativity rated as excellent, indicating an innovative and forward-thinking approach. Functionality, spatial efficiency, technical proficiency, and representation were all rated as good, showcasing a strong and reliable application of design principles. ST-6 encountered no challenges in this environment, reflecting high comfort and mastery of conventional design methods.

VR/AR with Screens

In the VR/AR environment with screens, ST-6 maintained high engagement and efficiency. The design product in this environment was rated as very good, with creativity, functionality, and spatial efficiency all rated as excellent. This suggests that ST-6 adapted exceptionally well to the digital environment, utilizing the tools to enhance the design process and produce superior results. Technical proficiency and representation were also rated as excellent, indicating a clear and effective communication of ideas within the VR/AR medium. ST-6 experienced no challenges in this environment, further underscoring the student's strong adaptability and competence in using digital tools to achieve high-quality outcomes.

VR/AR with VR Headset

The VR/AR environment with the VR headset presented a seamless transition for ST-6, who demonstrated extensive engagement and exceptional efficiency in all phases of the design process. The design product in this environment was rated as very good across all criteria, including creativity, functionality, spatial efficiency, technical proficiency, and representation. ST-6 encountered no challenges in using the VR headset, reflecting a high level of comfort and skill in navigating the immersive environment. The student's ability to maintain high standards of design products in the VR headset environment indicates a strong mastery of this technology, with the potential to further enhance the architectural design process.

Conclusion

ST-6's experiences across the three design environments reveal high proficiency, adaptability, and creativity. The student excelled in the conventional design studio but thrived in the digital and immersive environments provided by VR/AR tools, with the screens and VR headset. The transition to these new technologies did not present any significant challenges, and ST-6 was able to leverage them to produce innovative and high-quality designs.

ST-6's experience underscores the value of incorporating XR technologies into design education, particularly for students with a natural aptitude for digital and immersive tools. The excellent outcomes achieved in the VR environments suggest that these technologies can significantly enrich the design process, allowing for more creative and effective solutions that might be more challenging to achieve with conventional methods alone.

The surveys, output assessments, and observations are consistent, showing that ST-6's performance improved progressively as the student moved from the conventional studio to the VR/AR environments. The student's ability to effectively integrate these new tools into the design process without encountering any major difficulties highlights a strong potential for using XR technologies to further enhance architectural education and practice.

ST-7 Design Experience Analysis

Conventional Design Studio

ST-7 exhibited high engagement and proficiency in the conventional design studio environment. The student extensively interacted with the tools and the environment, demonstrating excellent efficiency across all phases of the design process, including analysis, synthesis, concept development, design improvement, and final presentation. The design product was rated as excellent overall, with creativity, functionality, and spatial efficiency all rated as very good, reflecting a thoughtful and effective approach. Technical proficiency and representation were rated as very good, indicating solid execution with some areas for enhancement. ST-7 encountered no challenges in this environment, indicating a strong comfort level with conventional design methods.

VR/AR with Screens

In the VR/AR environment with screens, ST-7 maintained strong engagement but faced minor challenges. The design product was rated as very good overall, with creativity rated as good. Functionality and spatial efficiency were rated excellent, indicating adept use of digital tools and a successful transition from conventional methods. Technical proficiency and representation were also rated as very good, showing a high standard of work, though with room for further refinement. Despite the minor challenges with the tools and environment, ST-7 was able to adapt effectively to the digital medium and produce high-quality design outcomes.

VR/AR with VR Headset

The VR/AR environment with the VR headset presented some challenges for ST-7, particularly in the concept and design improvement phases, where efficiency dropped to moderate. The design product in this environment was rated as very good overall. Creativity, functionality, and spatial efficiency were rated as very good, reflecting consistent quality but not as strong as in the other environments. Technical proficiency and representation remained good, indicating a solid execution despite the challenges. ST-7 experienced minor difficulties with the tools and environment but was still able to maintain a good level of engagement and motivation. The transition to the VR headset, while not as seamless as with screens, still demonstrated potential for further development and adaptation.

Conclusion

ST-7's experiences across the three design environments reveal a strong foundation in conventional design methods and a good ability to adapt to digital tools, particularly in the VR/AR with screens environment. The student's design product was consistently high across all environments, though the VR headset presented more challenges, particularly in the design improvement and concept phases.

ST-7's experience suggests that the student could enhance her design outcomes even further with further practice and more advanced tools, particularly in the VR headset environment. The overall analysis highlights the value of integrating XR technologies into design education, particularly for students who are already proficient with conventional methods but want to expand their skills and capabilities in digital and immersive environments.

The surveys, output assessments, and observations are consistent, showing that while ST-7 is comfortable and proficient with conventional methods, she is willing and able to adapt to new technologies, particularly XR tools. The student's preference for using all three methods together reflects an understanding that each environment offers unique benefits and can complement the others in the design process.

ST-8 Design Experience Analysis

Conventional Design Studio

ST-8 demonstrated high engagement and proficiency in the conventional design studio environment. The student extensively interacted with the tools and environment, showing excellent efficiency across all phases of the design process, including analysis, synthesis, concept development, design improvement, and final presentation. The design product was rated as very good overall, with creativity, functionality, and spatial efficiency all rated as excellent, reflecting a sophisticated understanding of design principles. Technical proficiency and representation were both rated as very good, indicating well-executed technical aspects and clear visual communication. ST-8 encountered no challenges in this environment, indicating strong comfort and competence with conventional design methods.

VR/AR with Screens

In the VR/AR environment with screens, ST-8 maintained strong engagement and produced excellent design outcomes. The design product was rated as very good overall, with creativity, functionality, and spatial efficiency all rated as excellent, indicating a successful adaptation to the digital environment. Technical proficiency was rated very good, and representation was rated excellent, showcasing high detail and clarity. ST-8 experienced no challenges in this environment, demonstrating effective use of digital tools and strong motivation throughout the process.

VR/AR with VR Headset

The VR/AR environment with the VR headset presented a slight decrease in efficiency and creativity for ST-8. While the design product was still rated as very good overall, creativity, technical proficiency, and spatial efficiency were rated as very good rather than excellent. Representation was rated as very good, suggesting consistent quality but with potential for further refinement. Despite the slight decrease in creativity, ST-8 maintained strong engagement and encountered no challenges in this environment, indicating good comfort and adaptation to the immersive VR environment.

Conclusion

ST-8's experiences across the three design environments reveal a strong foundation in conventional design methods and a good ability to adapt to digital tools, particularly in the VR/AR with screens environment. The student's design product was consistently high across all environments, with a slight drop in creativity and efficiency when using the VR headset. However, ST-8's ability to maintain strong engagement and overcome challenges in each environment suggests that the student could enhance their design outcomes even further with further practice and advanced tools, particularly in the VR headset environment.

ST-8's experience suggests that integrating XR technologies into the design process can provide valuable perspectives and enhance overall design outcomes, particularly when used in conjunction with conventional methods. The overall analysis highlights the importance of providing students with opportunities to explore and adapt to new technologies, as this can lead to more innovative and effective design solutions.

The surveys, output assessments, and observations are consistent, showing that while ST-8 is comfortable and proficient with conventional methods, it is willing and able to adapt to new technologies. The student's preference for VR reflects an understanding that the environment offers ease of perception.

ST-9 Design Experience Analysis

Conventional Design Studio

ST-9 demonstrated outstanding engagement and efficiency in the conventional design studio environment. The student extensively interacted with both the environment and the tools, showcasing excellent proficiency across all phases of the design process. This includes analysis, synthesis, concept development, design improvement, and final presentation. The design product was rated as very good overall, with creativity, functionality, and spatial efficiency all rated as excellent. Technical proficiency and representation were also excellent, indicating a strong mastery of the design process and effective communication of ideas. ST-9 encountered no challenges in this environment, demonstrating a solid foundation in conventional design methods.

VR/AR with Screens

In the VR/AR environment with screens, ST-9 maintained high engagement and efficiency, producing excellent design outcomes. The design product was consistently rated as very good across all criteria, including creativity, functionality, spatial efficiency, technical proficiency, and representation. This reflects a successful and skilled adaptation to digital tools and environments.

ST-9 encountered minor challenges in using the tools but overcame these without significant impact on the design process, demonstrating adaptability and strong motivation.

VR/AR with VR Headset

In the VR/AR environment using the VR headset, ST-9 showed extensive engagement but experienced a slight decrease in efficiency, particularly in the design, analysis, synthesis, concept phases, and design development, where the performance was rated as moderate. Functionality and spatial efficiency remained very good, with creativity rated slightly lower at very good. Technical proficiency and representation were both rated as very good, indicating consistency. The student encountered minor challenges related to tool usage and engagement, suggesting that while ST-9 was highly motivated, there was some difficulty in adapting to the immersive VR environment.

Conclusion

ST-9's experiences across the three design environments highlight a strong proficiency in conventional design methods and a good ability to adapt to digital tools, particularly in the VR/AR with screens environment. While still strong, the student's performance in the VR headset environment suggests room for improvement in fully adapting to and leveraging the immersive VR environment. ST-9's preference for integrating VR headsets into future design projects reflects an understanding of the potential benefits of immersive environments, particularly for testing and refining designs in a more realistic context. However, the student also recognizes the importance of a strong foundation in conventional methods and the value of using these tools to enhance the overall design process. Overall, ST-9's experience underscores the importance of providing opportunities to explore and adapt to new technologies and the need for continued practice and familiarization with these tools to unlock their potential in the design process fully.

The surveys, design assessments, and observations suggest that while ST-9 is comfortable and excels in conventional and screen-based digital design, the transition to a fully immersive VR environment posed some challenges, particularly in the early stages of the design process. However, the student's motivation and engagement remained high, indicating a strong willingness to learn and adapt to new technologies.

ST-10 Design Experience Analysis

Conventional Design Studio

ST-10 exhibited extensive engagement and interaction in the conventional design studio environment but faced moderate efficiency in various phases of the design process, including design, analysis, synthesis, concept development, design improvement, and final presentation. The overall design product was rated as fair, with creativity, functionality, and spatial efficiency all rated at a basic level. Technical proficiency and representation were also rated as fair, indicating significant room for improvement in these areas. ST-10 encountered moderate challenges in the design process and faced significant challenges with motivation, which may have impacted the overall performance in this environment.

VR/AR with Screens

In the VR/AR environment using screens, ST-10 showed active engagement and good design efficiency. The design product improved in this environment, with creativity and representation rated fair. However, technical proficiency, functionality, and spatial efficiency remained fair, suggesting that while ST-10 adapted well to the digital environment, there were still challenges in fully optimizing the design for practical and spatial aspects. The student faced minor challenges with tool usage and engagement, which were overcome, but motivation remained a moderate challenge.

VR/AR with VR Headset

In the VR/AR environment using a VR headset, ST-10 maintained extensive engagement and interaction, demonstrating good efficiency across various phases of the design process. Creativity, technical proficiency, and representation were consistently rated as good, indicating a successful adaptation to the immersive environment. However, functionality and spatial efficiency remained fair, reflecting ongoing challenges in maximizing the potential of VR technology for practical design applications. The student faced minor challenges in using the tools and engaging with the environment but managed to maintain motivation throughout the process.

Conclusion

ST-10's experiences across the three design environments reveal a clear progression in adapting to and utilizing digital tools, particularly in the VR/AR environments. While the student faced significant challenges in the conventional design studio, the shift to digital tools, particularly the VR headset, led to improved performance and a better understanding of spatial and functional aspects of design. ST-10's preference for using VR in future design projects reflects an appreciation for the potential of these tools to revolutionize the design process, particularly in visualizing and experiencing designs at a 1:1 scale. However, the student also recognizes the value of integrating conventional methods and screen-based tools to provide a comprehensive approach to design. Overall, ST-10's experience highlights the importance of continued practice and familiarization with digital and immersive tools and the need for further development of technical skills to fully capitalize on these technologies' potential in architectural design.

The surveys, design assessments, and observations suggest that ST-10 benefits from VR technology's immersive and interactive nature, which offers a more tangible understanding of design at a human scale. However, there are still challenges to be addressed in fully leveraging these tools to enhance functionality and spatial efficiency in design.

ST-11 Design Experience Analysis

Conventional Design Studio

ST-11 demonstrated extensive engagement and interaction within the conventional design studio environment. The student showed excellent efficiency in all phases of the design process, including design, analysis, synthesis, concept development, design improvement, and final presentation. The overall design product was rated as very good, with creativity, functionality, and spatial efficiency consistently strong. Technical proficiency and representation were also rated as very good, reflecting solid execution and clear communication. ST-11 did not face any challenges in this environment, indicating a high level of comfort and skill in conventional design methods.

VR/AR with Screens

In the VR/AR environment using screens, ST-11 showed extensive engagement and demonstrated extreme efficiency in the design process. The design product improved, with creativity rated as very good, showing a strong ability to leverage digital tools to enhance the design narrative. Functionality and spatial efficiency remained very good, translating practical design aspects into a digital format. Technical proficiency and representation were rated as very good, maintaining a high level of detail and understanding. ST-11 experienced no challenges using the tools, engaging with the environment, or completing the design process, indicating a seamless transition to digital design methods.

VR/AR with VR Headset

In the VR/AR environment using a VR headset, ST-11 maintained extensive engagement and interaction, demonstrating extreme efficiency across all phases of the design process. The design product was consistently very good, with particularly strong functionality and spatial efficiency. Creativity was rated as good, showing consistent performance across different platforms. Technical proficiency and representation were also rated as very good, demonstrating competent handling of VR technologies and communication. ST-11 experienced no significant challenges in this environment, though minor challenges with motivation were noted, which did not seem to affect the overall performance.

Conclusion

ST-11 exhibited high competence and adaptability across all three design environments, excelling particularly in the VR/AR environments. The student effectively utilized digital tools and VR technology to enhance the design process, showing a strong understanding of spatial relationships and practical design considerations. ST-11's preference for using all environments together reflects a comprehensive approach to design, recognizing the unique benefits that each environment offers. This integrated approach will likely enhance students' innovation ability and create more nuanced and well-rounded designs.

Overall, ST-11's experience highlights the importance of combining conventional design methods with emerging technologies to create a more dynamic and effective design process. The student's ability to easily navigate these different environments suggests a strong potential for success in the evolving field of architectural design.

The surveys, design assessments, and observations suggest that ST-11 is well-equipped to integrate XR technologies into the design process and can leverage these tools for innovative and efficient design solutions. The consistent performance across different platforms indicates a strong adaptability and a solid foundation in both conventional and digital design methods.

The design experiences across three different environments and tools show that integrating XR technologies in architectural design education has varying impacts depending on the students' individual experiences (Table 4.4).

Table 4.4 The design experiences of each student across three different design environments: Conventional Studio, Screens (VR/AR), and VR Headset.

	Conventional Studio	Screens (VR/AR)	VR Headset	Overall Evaluation
ST-1	**Excelled, Comfortable**: Good design, highly engaged, mastered conventional tools.	**Engaged, Adapted**: Slightly less engaged, faced minor challenges, output remained good but with slight drop in technical proficiency.	**Engaged, Challenged**: Moderate challenges in concept studies, good output with same spatial efficiency, recognized VR potential but noted it as a lack of creativity.	**Prefers a hybrid approach**, suggests integrating XR with conventional methods for best outcomes.
ST-2	**Excelled, Comfortable**: Good designs, engaged, adapted well despite initial unfamiliarity.	**Moderate Challenges**: Fair output, minor struggled with concept development and tool adaptation, creativity functionality and efficiency reduced.	**Slightly Challenged, Fair Output**: Fair output but faced difficulties with tool usage, maintained creativity, struggled to fully leverage VR potential.	**Hybrid approach preferred**, acknowledges challenges with XR, needs more familiarity with tools.
ST-3	**Excelled, Comfortable**: Very good designs, highly engaged, no challenges, strong across all aspects.	**Adapted, Maintained**: Slight dip in ease, minor tool challenges, but output remained very good, showcasing adaptability.	**Challenged, Overcame**: Faced initial challenges, maintained efficiency, ultimately delivered very good design after mastering VR tools.	**High adaptability**, thrives with XR, suggests XR technologies enhance design education significantly.
ST-4	**Moderate, Struggled**: Fair output, limited efficiency, struggled with motivation and engagement, basic competency.	**Improved, Engaged**: Very good output, better engagement, leveraged digital tools for enhanced creativity, spatial efficiency improved.	**Engaged, Challenged**: Fair output, preferred VR for practicality, faced moderate challenges, noted improvements in creativity but continued struggles with efficiency.	**Prefers VR tools**, sees growth potential in XR, struggles with conventional methods.
ST-5	**Excelled, Comfortable**: Very good output, highly engaged, well-rounded design approach, no significant challenges.	**Engaged, Challenged**: Fair output, struggled with creativity, functionality and spatial efficiency, needed more advanced tools.	**Challenged, Engaged**: Fair output, significant challenges adapting to VR, struggled with creativity, functionality and efficiency.	**Strong in conventional methods**, recognizes XR's potential, especially for 3D visualization, but needs advanced tools.
ST-6	**Exceptional, Mastered**: Good output, highly creative, no challenges, demonstrated strong and reliable design application.	**Efficient, Thrived**: Very good output, adapted extremely well, leveraged tools to enhance design process, no challenges faced.	**Seamless, Mastered**: Very good output, maintained high standards across all aspects, fully comfortable with VR, no challenges faced.	**Highly adaptable**, excels in XR, sees it as a as a tool for enhancing the design process.
ST-7	**Proficient, Effective**: Very good output, consistent across phases, no challenges, solid technical execution.	**Adapted, High Quality**: Very good output, minor tool challenges, maintained strong functionality and efficiency, adapted well.	**Challenged, Consistent**: Very good output, faced moderate challenges in initial phases, maintained quality but less strong than other environments.	**Prefers an integrated approach**, strong in conventional methods, sees potential in XR with improved tools.
ST-8	**Proficient, Creative**: Very good output, high engagement, well-executed design, no challenges.	**Adapted, High Quality**: Very good output, fully engaged, maintained creativity and efficiency, no challenges in digital adaptation.	**Slight Dip, Maintained**: Very good output overall, slight drop in creativity and efficiency, remained engaged, comfortable with VR environment.	**Comfortable in all environments**, sees XR as complementary to conventional methods, prefers VR for its ease to use.
ST-9	**Outstanding, Mastered**: Very good output, fully engaged, no challenges, highly proficient across all phases.	**Adapted, High Quality**: Very good output, very minor tool challenges, maintained strong efficiency and creativity.	**Challenged, Good Output**: Very good output, minor tool challenges, slight decrease in creativity, remained motivated and engaged.	**Recognizes XR challenges**, prefers VR headset because feels as a part of design and navigate easily.
ST-10	**Moderate, Struggled**: Fair output, significant challenges with motivation and efficiency, basic level across aspects.	**Improved, Active**: Fair output, adapted better to digital tools, maintained engagement, struggled with functionality and efficiency.	**Engaged, Progressed**: Fair output, maintained engagement, improved adaptation to VR, struggled with maximizing functionality and spatial efficiency.	**Progresses with digital tools**, benefits from XR for spatial understanding so prefers VR, mentions needs further development and practice.
ST-11	**Proficient, Comfortable**: Very good output, highly engaged, strong across all design phases, no challenges.	**Efficient, Enhanced**: Very good output, fully leveraged digital tools, improved slightly creativity, maintained high standards, no challenges.	**Seamless, High Quality**: Very good output, maintained consistency and high standards, slight motivation dip, but no significant challenges.	**Highly adaptable**, excels across all environments, prefers an integrated approach using all tools.

This case study focused on understanding the impact of XR technology design experience, disregarding academic levels. However, if we were to generalize based on academic levels: It found that 2nd-year students faced a steeper learning curve, but their engagement increased with familiarity. 3rd-year students adapted better, using foundational design knowledge but were more critical of XR (included VR/AR for this case study) limitations. 4th-year students effectively integrated these technologies with conventional methods, focusing on strategic applications. Overall, students at all levels have shown potential for growth and adaptation with adequate support, indicating that XR technologies represent a transformative threshold for conventional design education.

All students managed the design problem in each of the three environments by applying their individual approaches to the process and producing a final output. Students' motivation, ability to adapt to technology, proficiency with digital tools, and willingness to work with these new tools influenced the design outputs.

Design studio education consists of many components, and more design experience studies need to be conducted to understand the reaction and transformation of all these components using XR. However, this case study reveals that Extended Reality (XR) technologies, including VR/AR screens and headsets, significantly enhance architectural design education by providing immersive, interactive experiences that conventional methods alone cannot offer.

In the conventional studio environment, students demonstrated strong foundational skills in design, consistently performing well in creativity, functionality, and spatial efficiency. However, conventional methods sometimes limit students' ability to visualize and interact fully with their designs in three dimensions, leading to challenges in fully understanding spatial relationships and scale.

The introduction of VR/AR Screens improved the ability to visualize designs in a digital space, bridging the gap between two-dimensional sketches and three-dimensional thinking. Students generally adapted well to this environment, showing enhanced creativity and technical proficiency. The digital tools allowed for more precise control over design elements, though transitioning from conventional methods to screens presented minor challenges, particularly in mastering the new tools.

VR Headsets provided the most immersive experience, allowing students to engage with their designs on a 1:1 scale. This environment significantly enhanced their understanding of spatial relationships and functionality, leading to more informed design decisions. However, the initial learning curve for using VR headsets was higher, with some students facing challenges in tool manipulation and maintaining creativity within the immersive environment. Despite these challenges, the overall impact was positive, with VR headsets offering unparalleled opportunities for experiential learning and real-time design adjustments.

In comparing these environments, it is clear that while conventional methods remain essential for foundational design skills, XR technologies—particularly VR Headsets—offer powerful tools for advancing architectural education. XR environments enable students to engage with their designs in more interactive, immersive, and spatially aware ways, leading to innovative and practical design solutions. Integrating XR technologies into the curriculum, alongside conventional methods, can significantly enhance the educational experience, equipping students with the skills needed to excel in a rapidly evolving architectural landscape.

The case study clearly illustrates that XR technologies have the potential to enhance and redefine the conventional design studio experience in architectural education. By offering immersive, interactive, and spatially aware environments, XR tools allow students to engage with their designs in ways that were previously unattainable with conventional methods. This capability to visualize and interact with designs at a 1:1 scale, adjust in real-time, and explore spatial relationships with unparalleled depth suggests that XR could evolve to become a threshold technology in architectural design education.

While conventional methods will likely remain fundamental for developing core design skills, the growing sophistication and accessibility of XR technologies indicate that they could become central to the future design studio. As these tools continue to advance, their integration into educational curricula could lead to a significant shift in how architectural design is taught and practiced, potentially setting a new standard for what constitutes a comprehensive design education. In this way, XR technologies are not just an enhancement but a transformative force that could reshape the landscape of architectural education, pushing the boundaries of creativity, innovation, and practical design solutions.

Chapter 5

Conclusions and Future Prospects

5.1 Conclusions

Integrating XR technologies into architectural design education extends its impact beyond the classroom. By enhancing accessibility, reducing environmental impact, promoting collaboration, fostering design innovation, and preparing future professionals, XR contributes to global sustainability and societal progress. This technology represents a pedagogical advancement and a means to address pressing societal and environmental challenges through architectural design.

The introductory chapter sets the stage for the dissertation by emphasizing the importance of integrating XR (Extended Reality) technologies into architectural design education. It outlines the research scope, which explores the potential of XR technologies to revolutionize architectural education by enhancing visualization, spatial understanding, and creativity. The chapter establishes the methodological framework and highlights the significance of adapting educational practices to meet the evolving demands of the architectural profession.

Chapter 2 traces the historical evolution of architectural design studio education, from the early writings of Vitruvius to the modern studio-based learning environments. The chapter underscores the impact of significant milestones, such as establishing the Ecole des Beaux-Arts and the Bauhaus model, on contemporary design pedagogy. It concludes that understanding this historical context is crucial for effectively integrating XR technologies, as it provides a foundation for embracing new educational tools and methodologies that enhance the learning experience.

Chapter 3 provides an in-depth exploration of XR technologies, including VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality), and their applications in architectural design education. The chapter concludes that XR technologies offer significant potential to enhance architectural education by providing immersive and interactive learning environments. These technologies bridge the gap between theoretical knowledge and practical experience, improving spatial awareness, engagement, and the overall quality of design solutions students produce.

Chapter 4 presents a detailed case study on the practical application of XR technologies in architectural design studios. The findings indicate that XR tools, particularly VR headsets, significantly improve students' ability to visualize and interact with their designs in three dimensions. Despite some technical challenges, the case study concludes that XR technologies enhance the overall design experience, promoting creativity, collaboration, and more effective design processes. The positive impact on students' engagement and innovation underscores the value of integrating XR technologies into architectural education.

The integration of XR technologies into architectural design education offers substantial benefits in terms of enhanced visualization, spatial understanding, engagement, and innovation. Despite some challenges, the overall positive impact on students' learning experiences and outcomes underscores the transformative potential of XR technologies in architectural design education. This dissertation advocates for the broader adoption of XR technologies to create a more dynamic, innovative, and effective learning environment, ultimately preparing students for the evolving demands of the architectural profession (Table 5.1).

Table 5.1 Research questions, objectives, and results

Research Questions	Objectives	Results
how does integrating XR technologies (VR, AR, MR) affect the design learning experience and outcomes in architectural design studio education (ADSE) compared to conventional ADSE?	to investigate the integration, effectiveness, and challenges of Extended Reality (XR) technologies within architectural design studio education, aiming to provide insights for enhancing pedagogical practices in the field.	integrating XR technologies (VR, AR, MR) in architectural design studio education (ADSE) enhances design learning experience and outcomes compared to conventional education.
how do XR technologies impact student engagement and motivation in ADSE?	to examine the diverse impacts of Extended Reality (XR) technologies on design education experiences, including their influence on student learning outcomes, pedagogical approaches, creative processes, and overall engagement within educational settings.	XR technologies positively impacts student engagement and motivation.
how do XR technologies affect the efficiency and effectiveness of design processes?	to investigate and analyze the impact of Extended Reality (XR) technologies on design experiences, encompassing spatial perception, creativity, user engagement, and the overall design process, with the aim of providing insights into leveraging these technologies to optimize design outcomes and foster innovation.	XR technologies in ADSE enhance real-time visualization, contributing to more effective and motivated design processes.

The findings contribute to the ongoing discourse on the role of technology in architectural education and highlight the societal impact and future prospects of XR technologies. By fostering a more inclusive, accessible, and innovative design education framework, XR technologies can significantly shape the future of architectural education and practice.

5.2 Societal Impact and Contribution to Global Sustainability

Integrating XR (Extended Reality) technologies into architectural design education transcends the boundaries of academia and extends its impact on society. This section explores the societal implications of XR technology adoption in architectural design studios and its potential contribution to global sustainability.

One of the notable societal impacts of incorporating XR technologies in design education is the democratization of access to architectural knowledge and skills. XR tools can reach a broader audience, including individuals in remote or underserved areas, fostering inclusivity in architectural education. This broader access has the potential to diversify the pool of future architects, contributing to a more inclusive and representative architectural profession.

Global sustainability is intrinsically linked to environmental conservation and reduced carbon emissions. Conventional architectural design practices often involve physical model-making, which consumes resources and generates waste. XR technologies promote virtual design prototyping and visualization, reducing the need for physical models and minimizing the environmental footprint associated with design education.

XR technologies facilitate collaboration among students, educators, and professionals from diverse locations. Virtual design studios can bring together participants worldwide, fostering a global perspective in architectural education. Collaborative projects that transcend borders can lead to innovative design solutions that address pressing global challenges, such as climate change and urbanization.

Society benefits from architectural innovations that address contemporary challenges. XR technologies enable students to engage in immersive, experiential learning, which empowers them to explore unconventional design solutions. The design innovations nurtured in XR-integrated studios have the potential to influence the built environment positively, promoting sustainable architectural practices.

As XR technologies become increasingly prevalent in the architectural profession, students with XR skills are better prepared for the industry's evolving demands. This contributes to the resilience of the architectural workforce and ensures that professionals can address emerging challenges related to sustainability, resilience, and digital transformation.

5.3 Future Prospects

Integrating XR (Extended Reality) technologies into architectural design education presents numerous promising future prospects. As XR technologies continue to advance, their capabilities are expected to improve significantly, making these tools more accessible, affordable, and user-friendly. Future research should focus on enhancing the resolution, frame rates, and ergonomic design of XR devices to provide more comfortable and immersive experiences for users. Additionally, the development of comprehensive educational frameworks that integrate XR technologies will be crucial. These frameworks need to be adaptable to the rapid pace of technological change and incorporate best practices for using XR tools in architectural design education. This includes the creation of standardized curricula that ensure consistency and quality in teaching methodologies across institutions.

Interdisciplinary collaboration is another exciting prospect offered by XR technologies. By fostering projects that involve architecture, computer science, engineering, and other fields, XR tools can be leveraged to solve complex design problems and drive innovation. Enhanced remote and hybrid learning environments are also on the horizon. The COVID-19 pandemic has underscored the importance of flexible learning modalities, and XR technologies can significantly enhance these by providing immersive and interactive virtual classrooms and design studios. Future research should explore the effectiveness of XR in these settings and develop strategies to address any associated challenges.

Ensuring a positive user experience and high usability for XR technologies will be essential as they become more integrated into architectural education. Future studies can focus on evaluating and improving the usability of XR tools, addressing issues related to user interface design, ease of use, and reducing physical strain during prolonged usage.

Moreover, long-term impact studies are needed to assess the effects of XR technologies on students' professional careers. Tracking graduates who have been trained with XR technologies can provide valuable insights into how these tools influence their performance, creativity, and adaptability in the architectural profession.

The adoption of XR technologies also raises important ethical and societal considerations, such as data privacy, digital equity, and the potential for technology-induced isolation. Future research should address these issues, exploring ways to ensure that XR technologies are used ethically and inclusively in educational settings. Additionally, the integration of XR technologies with other emerging technologies, such as Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT), holds great potential. For example, AI could be used to provide personalized learning experiences, while IoT could create smart, interactive learning environments.

In summary, the future prospects of integrating XR technologies into architectural design education are both promising and multifaceted. Continued research and development in these areas will help to fully realize the potential of XR tools, ultimately transforming architectural education and practice to meet the evolving demands of the 21st century.

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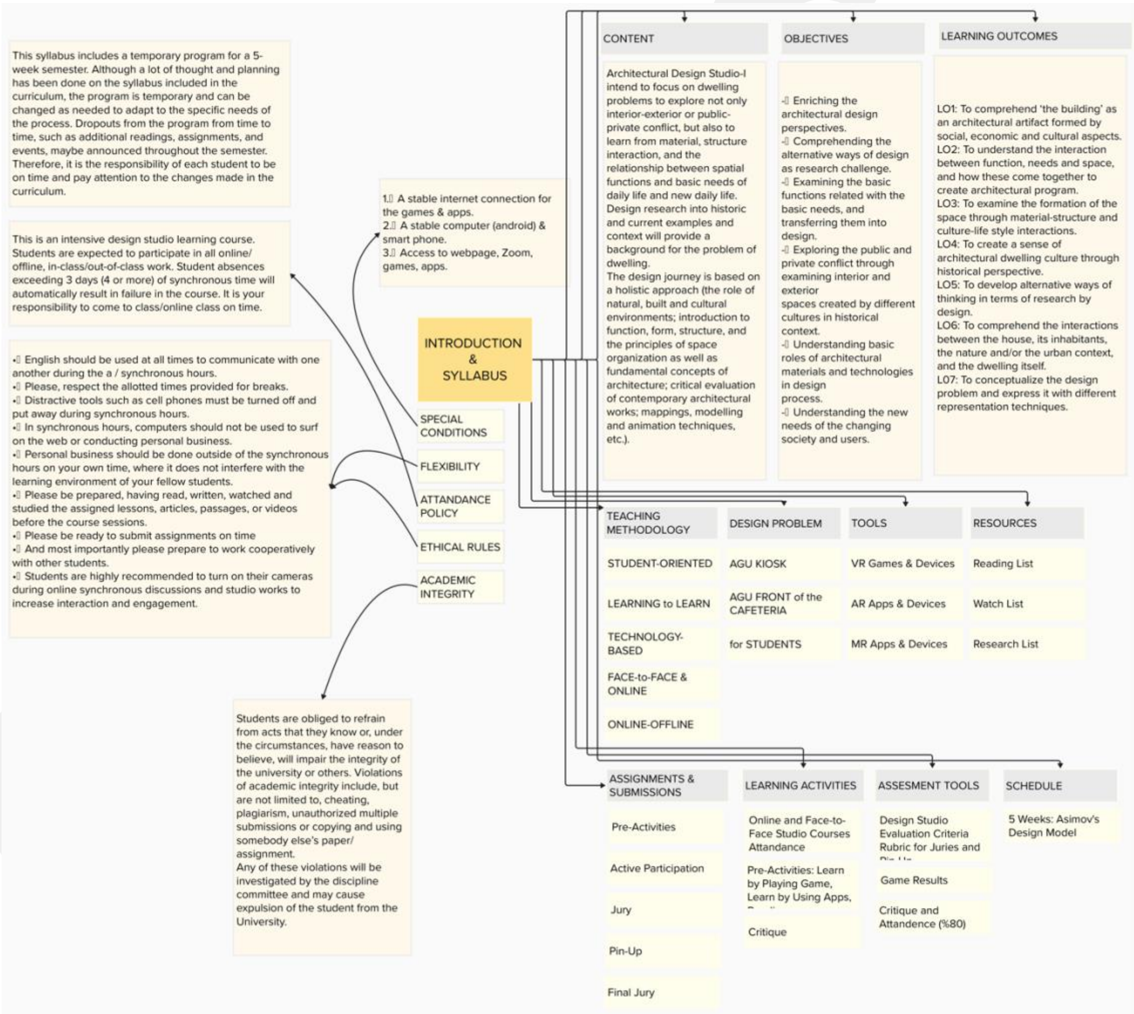
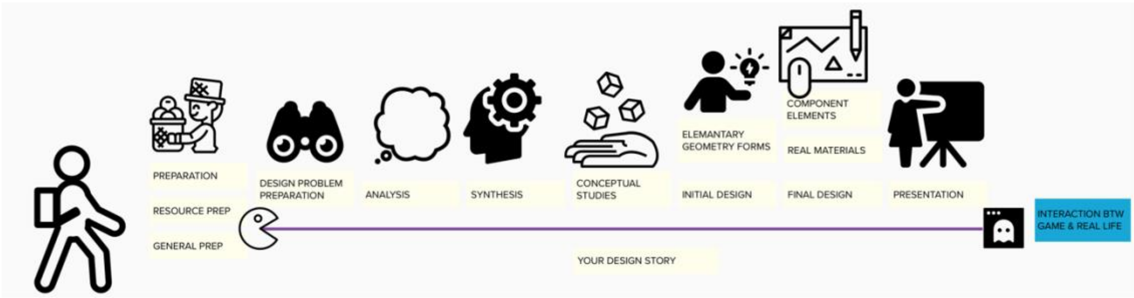
APPENDIX

1. Pre-Case Studies: Literature Reviews, Design Studies, Trials, Game Drafts.

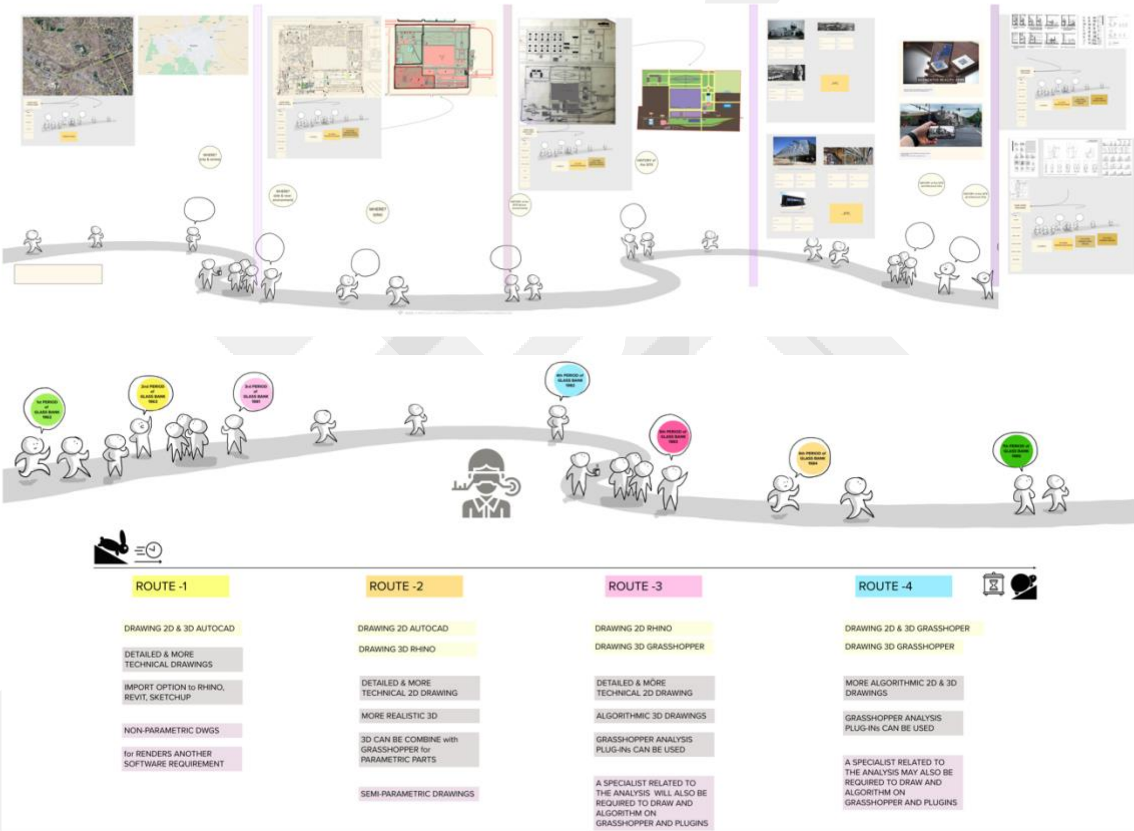
1.1 Architectural Design Education Components with XR Studies



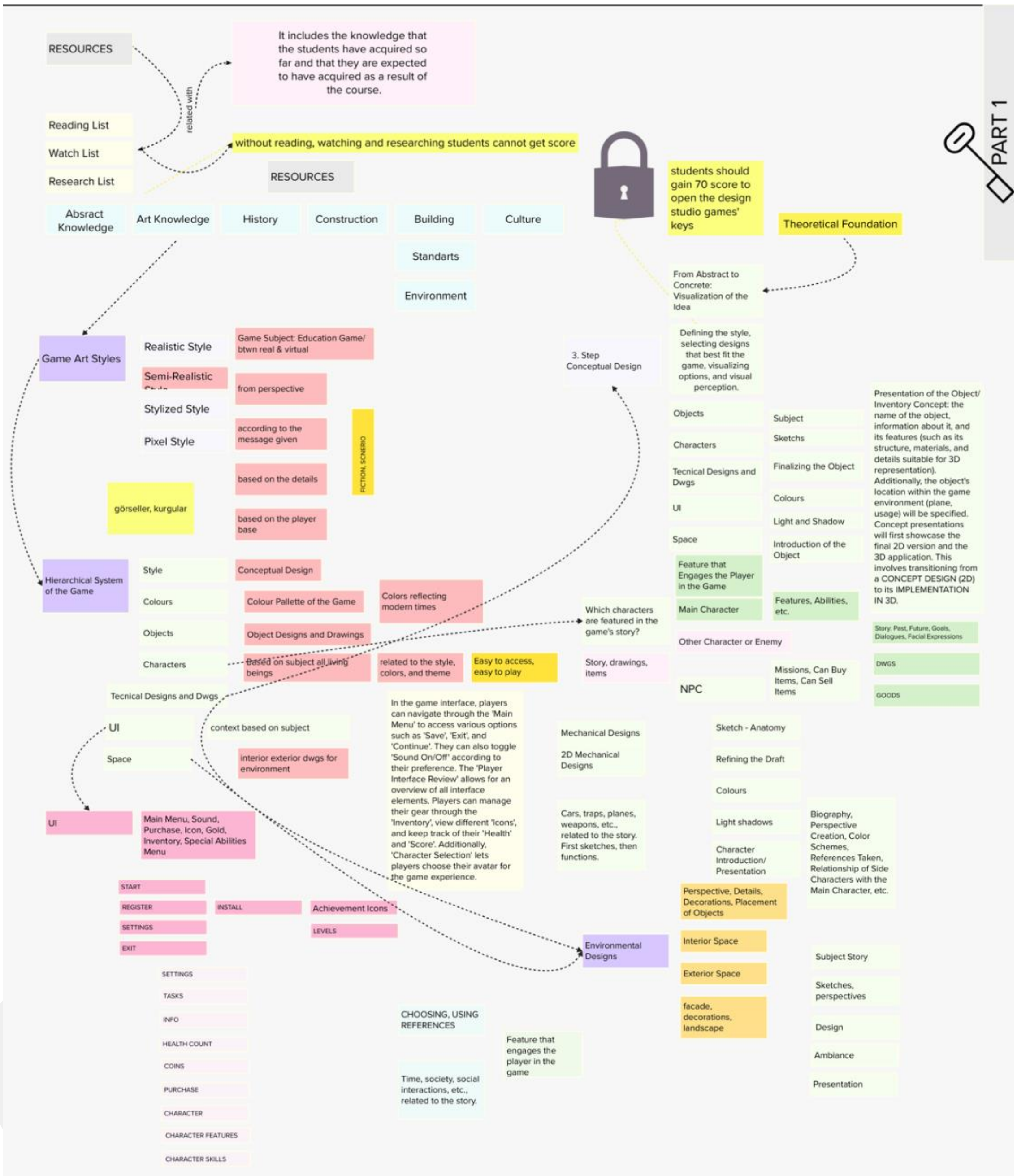
1.2 Design Process – Gamification Draft Study



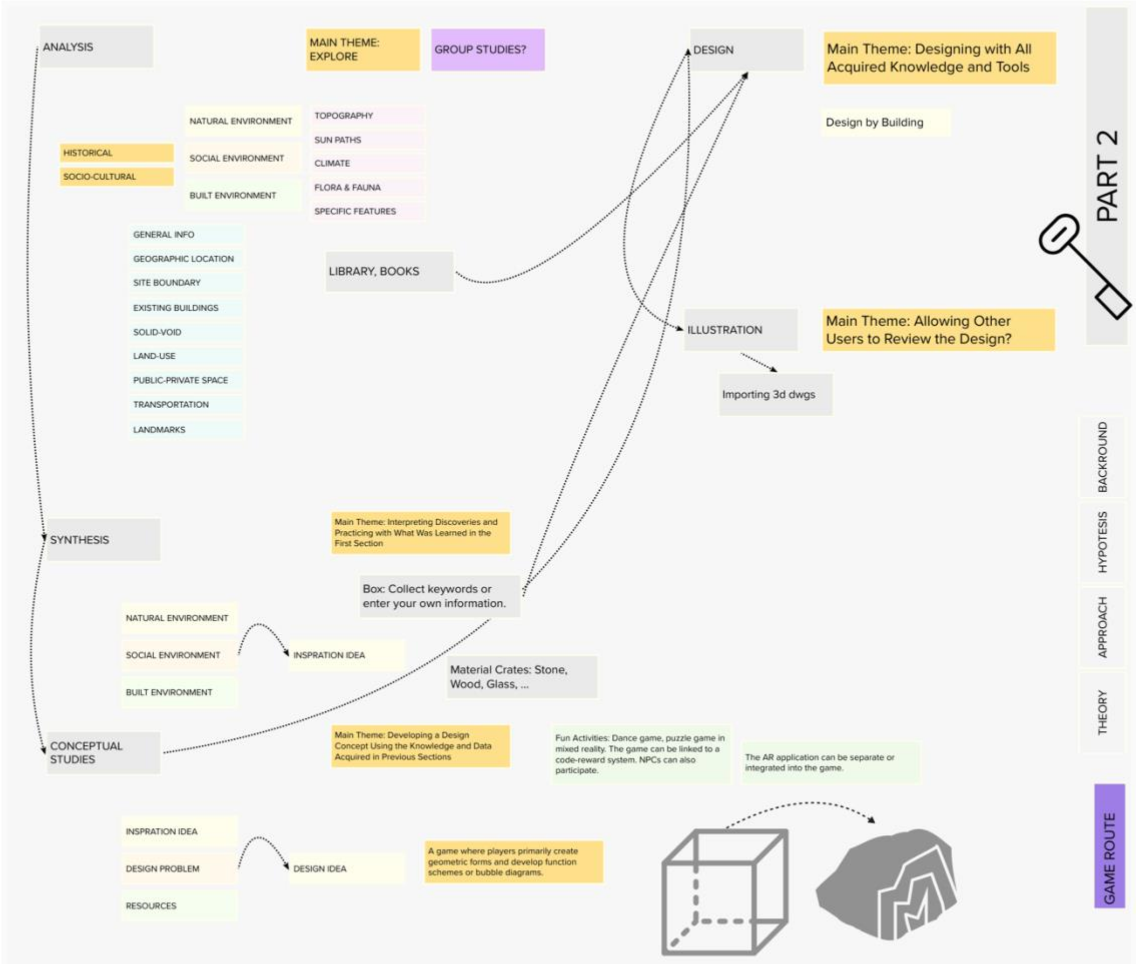
1.3 Content concept design for design studio education with VR & AR Draft Study



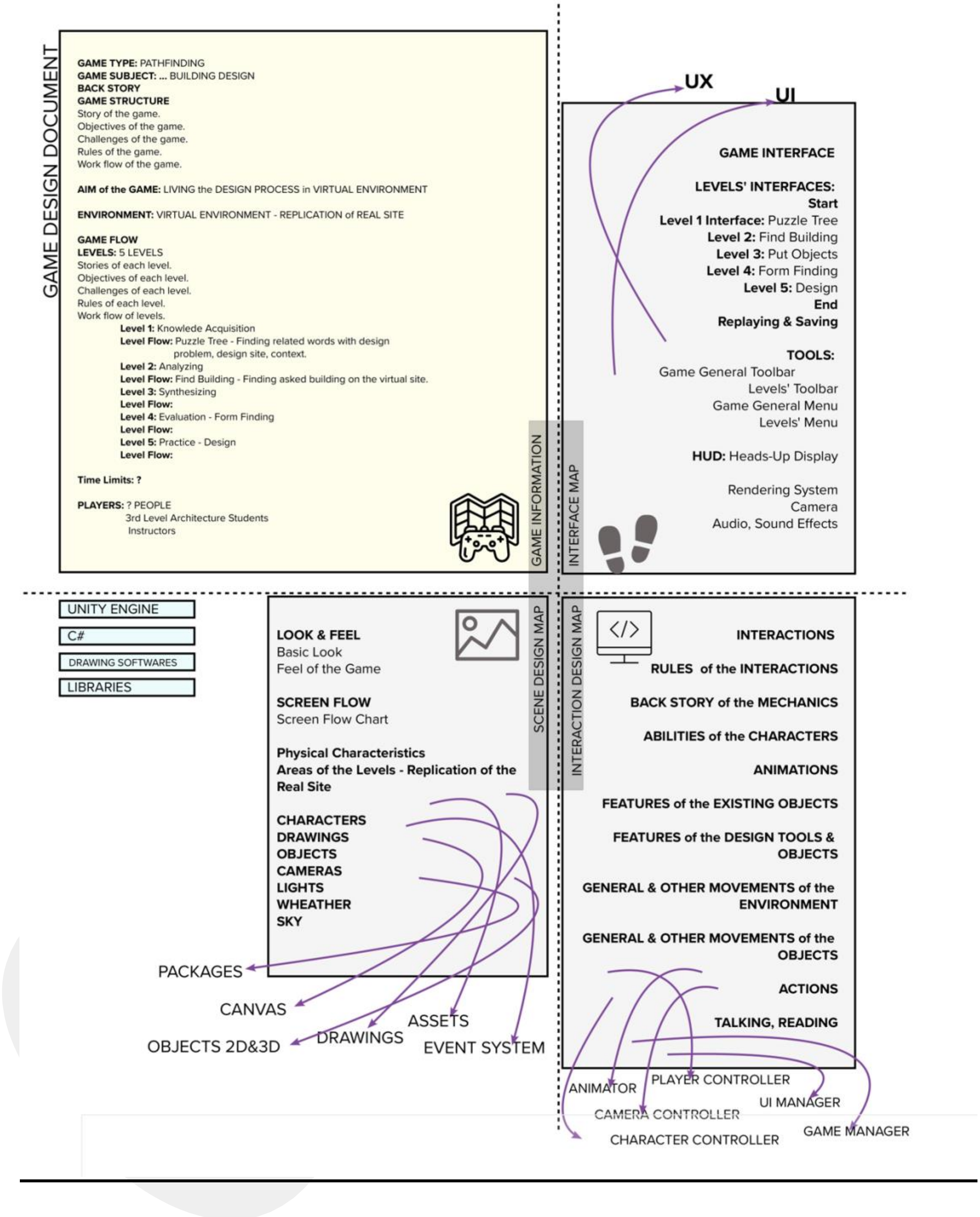
1.4 Game, game art, game technical research studies



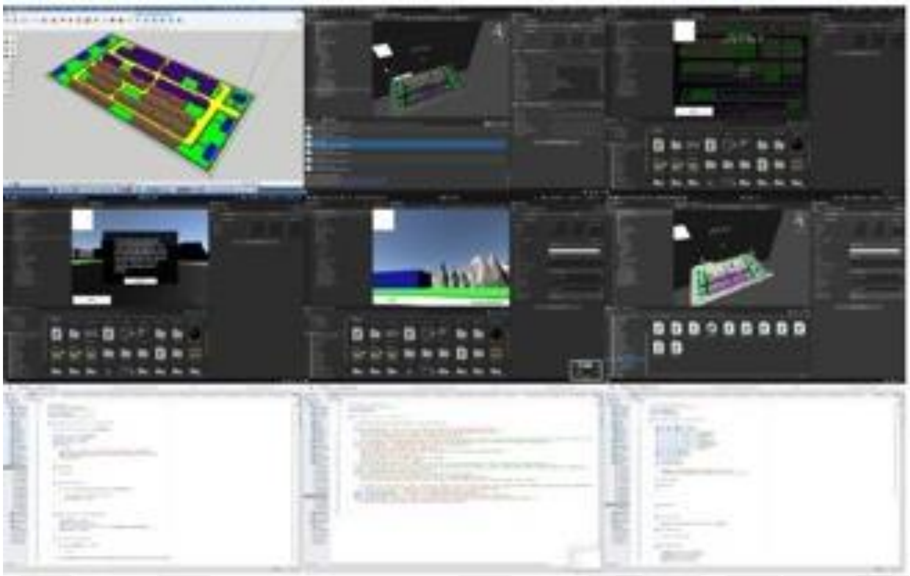
1.5 Game, game art, game technical research studies



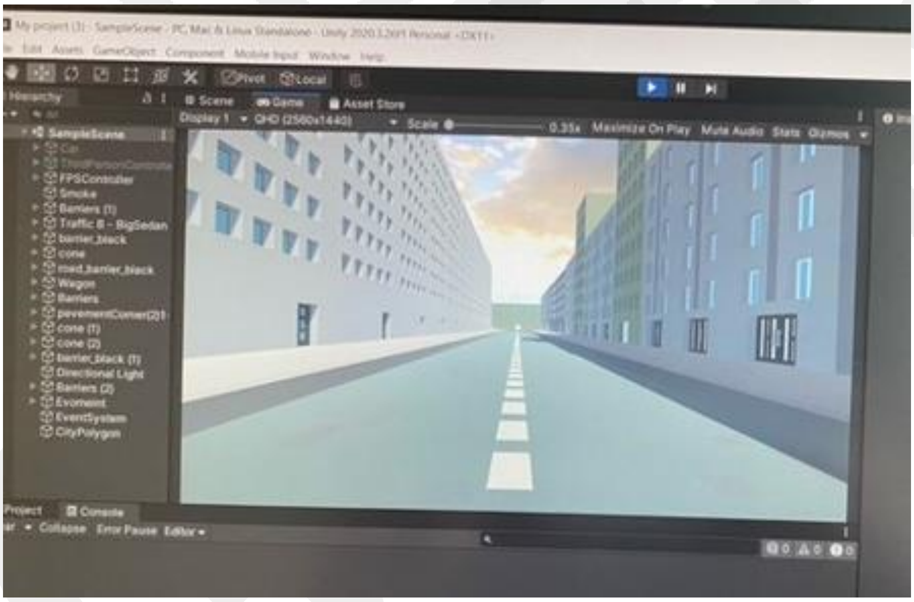
1.6 Game Design Documents Draft Studies



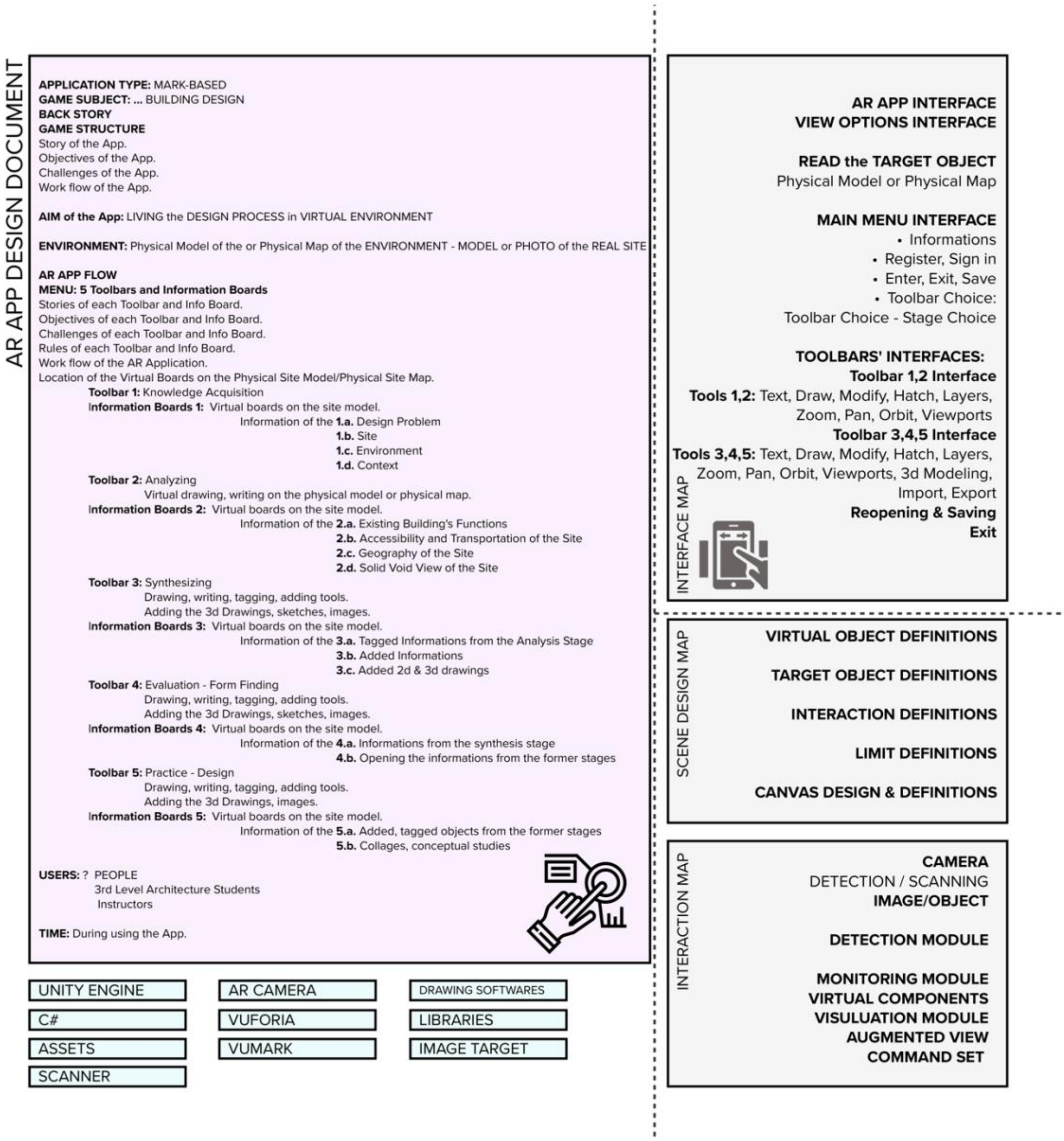
1.7 Game Trials: Finding Adress-Creating Mass Game Study



1.8 Game Trials: Game for the site analysis phase

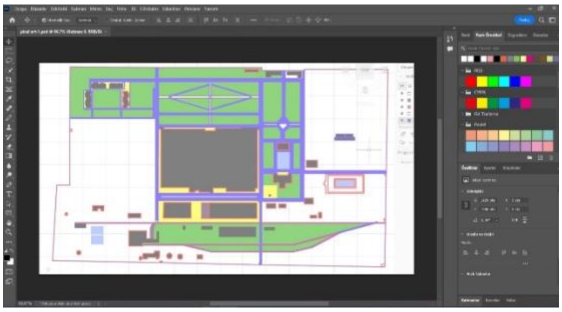


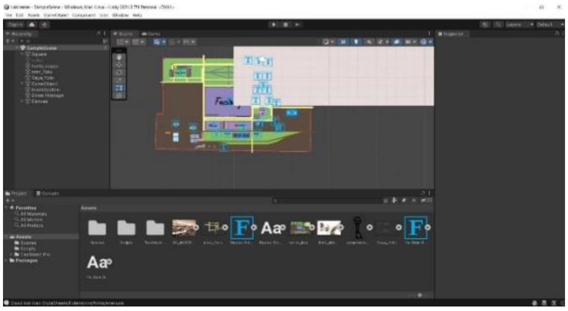
1.9 AR App Design Document Draft Studies

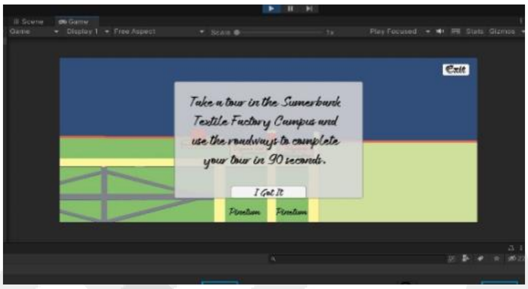


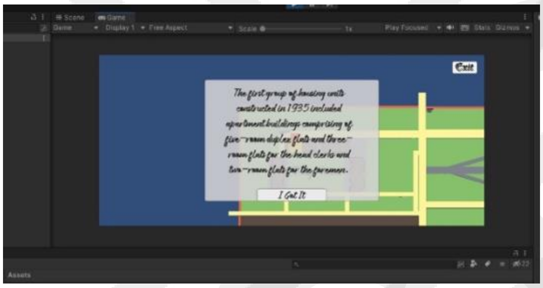
1.10 AR App Trial on Physical Model

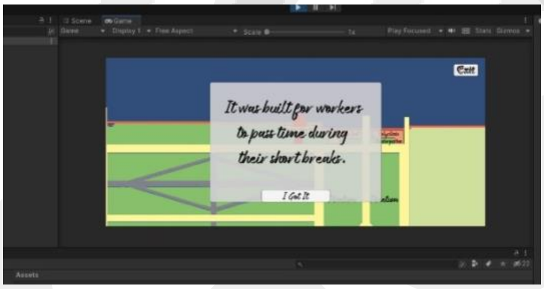
1.11 Game Trials: Pixel Art Game for analysis phase in Unity3D

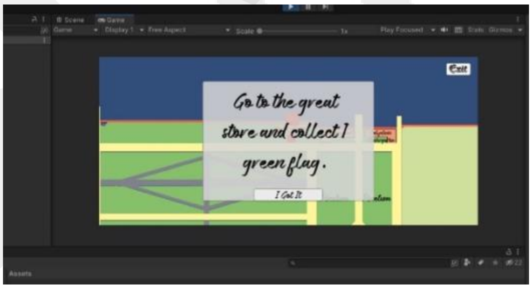


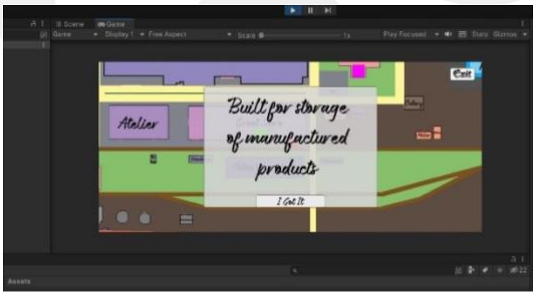


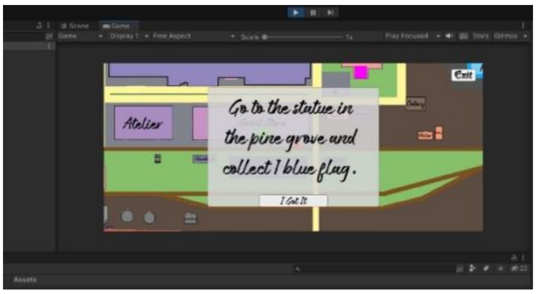




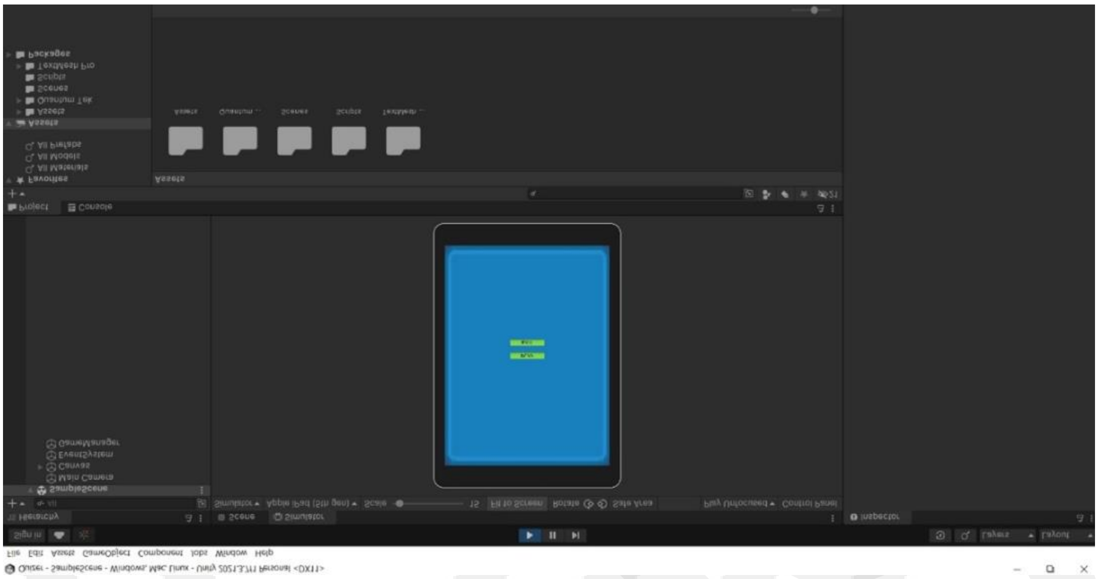


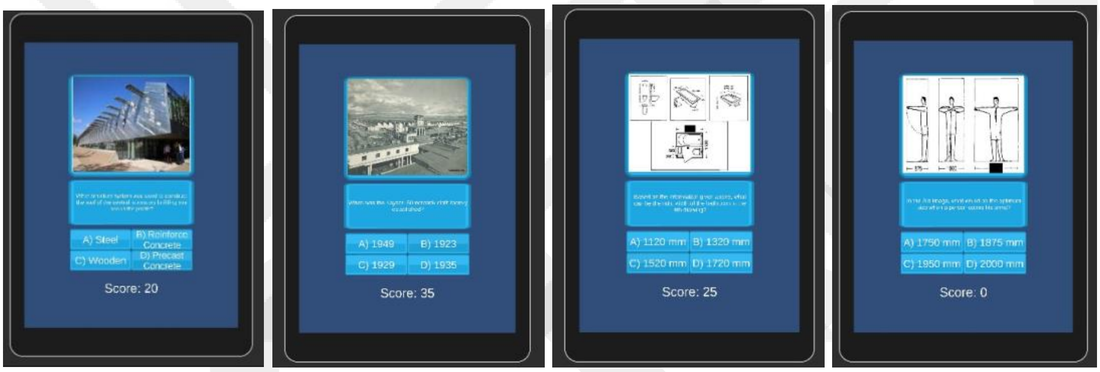






1.12 Game Trials: Knowledge contest game for analysis phase in Unity3D

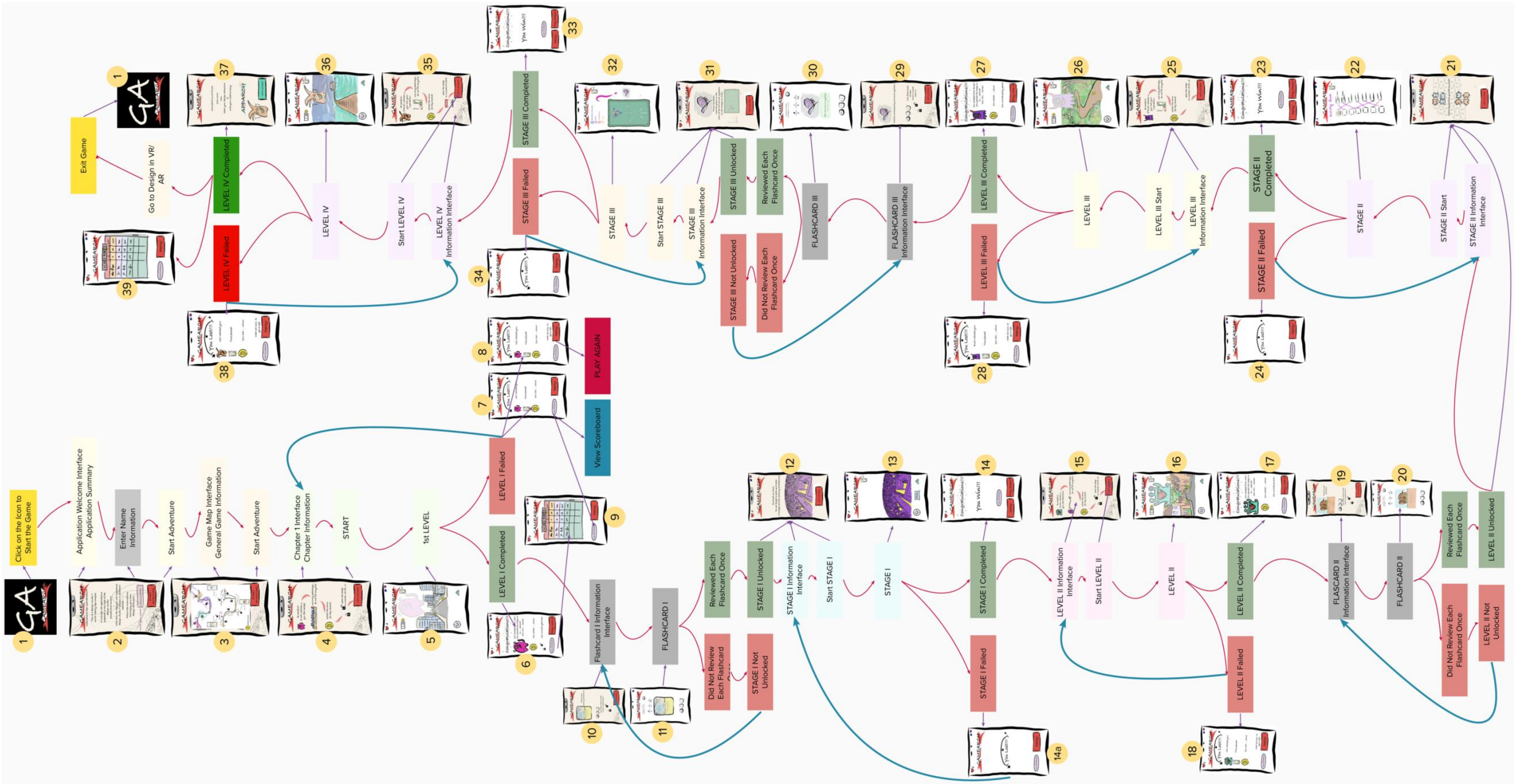




1.13 Game Trials: Advanced Game Operation Drafts

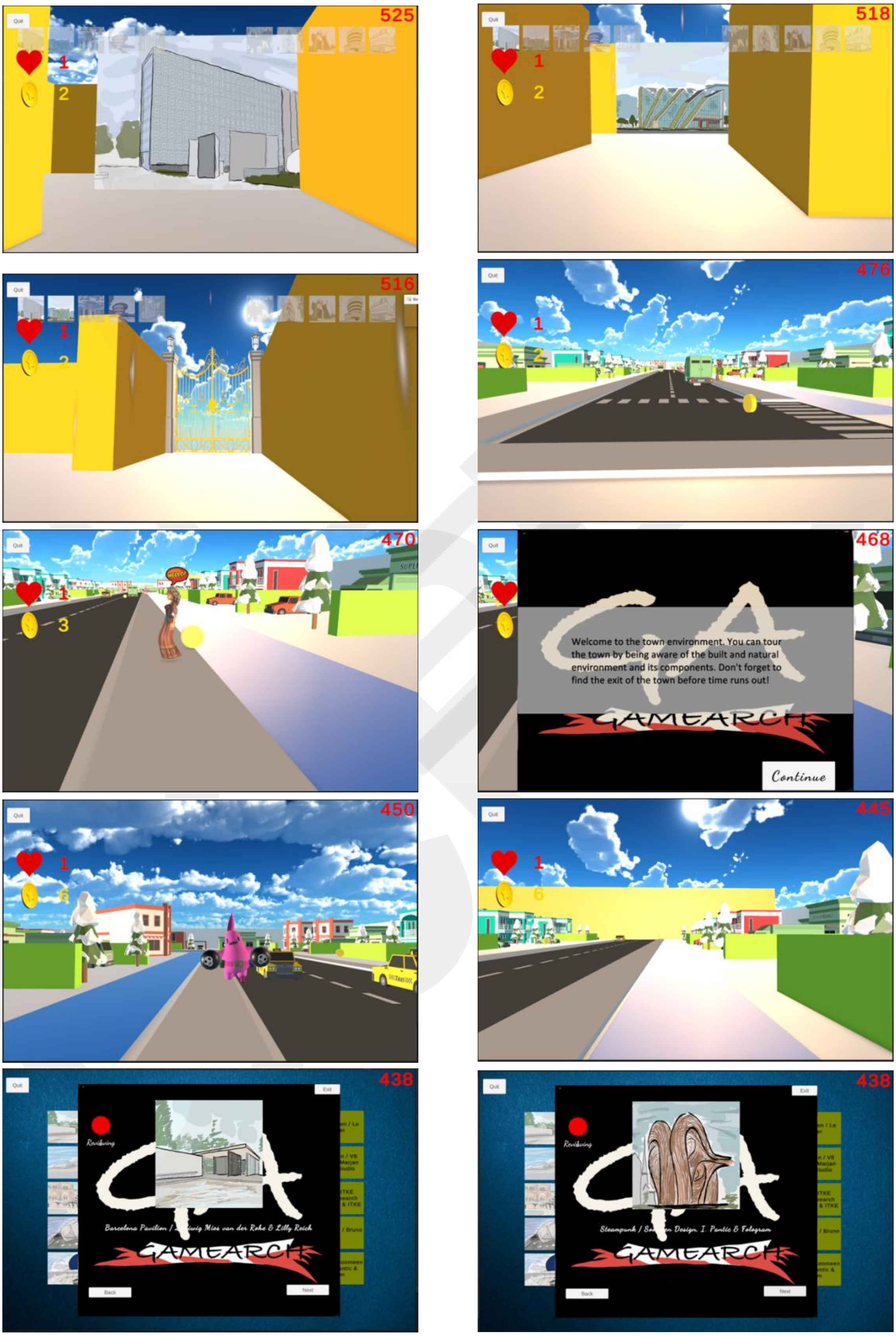
This map draft is a detailed user experience (UX) and user interface (UI) flowchart for a game application, outlining all the steps and player interactions throughout the game's development process. The map illustrates how the player will progress through different levels of the game, what screens they will encounter upon success or failure, and which interface elements will be used at various stages. It includes graphical representations of how the player is guided throughout the game, the sequence of completing specific tasks, and various informational and error screens. This draft serves as a guide for developing the mechanical and technical aspects of the game.

1.13 Game Trials: Advanced Game Operation Map



Legend for Game Operation Map:
1- Game Start Interface: The player begins the game by clicking the "Start Adventure".
2.-Application Welcome Screen: This screen captures player information, such as their name, and provides a button to initiate the adventure.
3- Game Map Interface: This interface displays the game map and general information, allowing players to navigate and begin their journey.
4- Chapter 1 Information: This section details Chapter 1(GameArch) and includes a "Start" button to begin the first chapter.
5- LEVEL I: Engages the player in the first level, where they interact with the level environment.
6- LEVEL I Completion: Confirms that the player has successfully completed LEVEL I and provides a button to proceed or see the Scoreboard.
7- LEVEL I Failure: This message informs the player of failure in LEVEL I and offers a view of the Scoreboard.
8- LEVEL I Failure: Play Again: Click to replay LEVEL I.
9- Scoreboard view: Offers Exit or Replay click.
10- FLASHCARD I: Provides content for the player to review, with navigation options to move through Flashcard I.
11- FLASHCARD I: Review Flashcards and offer next-previous clicks. At the end of this review, Stage 1 unlocks.
12- STAGE I: STAGE I Info and Start button that initiates the stage.
13- STAGE I: play STAGE I: labyrinth game.
14- STAGE I: STAGE I completed. View the scoreboard, replay, and go to the Level II buttons.
14a- STAGE I: STAGE I failed: replay and view scoreboard buttons.
15- LEVEL II Information: Prepare the player for LEVEL II by providing relevant details and a button to start the stage.
16- LEVEL II: Engages the player in the second level with interactive gameplay elements.
17- LEVEL II Completion: Confirms the player’s success in LEVEL II and provides a button to continue.
18- LEVEL II Failure: Informs the player of failure in LEVEL II and offers options to retry or review Flashcards.
19- Flashcard II: Offers content for the player to review, with navigation options next-previous through Flashcard II.
20- STAGE II Unlock after the player has reviewed Flashcard II, allowing them to start STAGE II OR review again.
21- STAGE II Info and Start button that initiates the stage.
22- STAGE II: Play STAGE I: matching game.
23- STAGE II: STAGE II completed. View the scoreboard, replay, and go to the Level III buttons.
24- STAGE II: STAGE II failed: replay and view scoreboard buttons.
25- LEVEL III Information: Prepare the player for LEVEL III by providing relevant details and a button to start the stage.
26- LEVEL III: Engages the player in the third level, offering advanced challenges.
27- LEVEL III: Provides information about LEVEL III and allows the start of the FLASHCARD III.
28- LEVEL III Failure: Informs failure in LEVEL III and offers options to retry.
29- FLASHCARD III Start: Review Flashcards and offer next-previous clicks. At the end of this review, Stage 1II unlocks.
30- Flashcard III: Provides content for the player to review, with navigation options.
31- STAGE III Unlock: Unlocks STAGE III after the player has reviewed Flashcard III, allowing them to start the stage.
32- STAGE III: Play STAGE III: party game.
33- STAGE III Completion: STAGE III completed. View the scoreboard, replay, and go to the Level IV buttons.
34- STAGE III Failure: Notifies failure in STAGE III and provides options to retry.
35- LEVEL IV Information: Prepare the player for LEVEL III by providing relevant details and a button to start the stage.
36- LEVEL IV: Engages the player in the third level, offering advanced challenges.
37- LEVEL IV Information: Prepares the player for LEVEL IV with the necessary information and a "Start" button.
38- LEVEL IV Failure: Notifies the player of failure in LEVEL IV and offers retry options.
39- SCOREBOARD: Informs the player about scores and GameArch finishes. Replay and Exit options.

2. Pre-Case Studies: GameArch (Play ScreenShots)


525
518
516
476
470
468
Welcome to the town environment. You can tour the town by being aware of the built and natural environment and its components. Don't forget to find the exit of the town before time runs out!
GAMEARCH
Continue
450
445
438
438


438
Let's Start
436
440
422
If you catch the OZI, you gain additional time.
Just use the pathways...don't hit anything!
Pass the stage to unlock LEVEL 3
Let's Start
416
410
HELLO!
409
Welcome to the forest environment. You can tour the forest by being aware of the natural environment and its components. Follow the path, and don't forget to find the forest's exit before time runs out!
Continue
401
369
steel
shell
Back
Next
369
steel
shell
Back
Next

2.1 GameArch Download QR

3. Case Study Materials – Background Data

3.1 Ethical Committee Approval

AGÜ

T.C.
ABDULLAH GÜL ÜNİVERSİTESİ REKTÖRLĞÜ
Etik Kurul

TÜRKİYE CUMHURİYETİ'NİN YÜZÜNCÜ YILI

Sayı : E-23934413-050.04-86964 14.03.2024
Konu : Kararlar

Sayın Ayşegül KIDIK

Üniversitemiz Etik Kurulu'nun 05.03.2024 tarihinde yapmış olduğu toplantıda, etik kurul başvurunuzun incelenmesi neticesinde; araştırmanızın etik açıdan uygun olduğuna karar verilmiş olup, onay belgesi ekte gönderilmiştir.

Prof.Dr. Alaattin ŞEN
Komisyon Başkanı

Ek:Kararlar (1 Sayfa)

Bu belge, güvenli elektronik imza ile imzalanmıştır.

Belge Doğrulama Kodu :BSA3D7RDER Belge Takip Adresi : https://www.turkiye.gov.tr/abdullah-gul-universitesi-ebys

Adres:Abdullah Gül Üniversitesi Sümer Kampüsü 38080, Kocasinan/Kayseri
Telefon:0 352 224 88 00 - 02 - 03 Faks:0 352 338 88 28
e-Posta:info@agu.edu.tr Web:www.agu.edu.tr
Kep Adresi:agu@hs01.kep.tr

Bilgi için: İbrahim ALSANCAK
Unvanı: Araştırma Görevlisi

ABDULLAH GÜL ÜNİVERSİTESİ ETİK
KURULU PROJE/ANKET ONAY FORMU

Proje Adı	Extended Reality Technologies and Design Experience
Projenin Niteliği	Surveys, Observations, In-depth Interviews
Projenin Araştırmacıları	Ayşegül Kidik, Burak Asiliskender

KARAR:

Proje etik açıdan uygun bulunmuştur. [X]

Projenin etik açıdan geliştirilmesi gerekmektedir. [ ]

Proje etik açıdan uygun değildir. [ ]

12/03/2024

ADI SOYADI	İMZA
Prof. Dr. Alaattin ŞEN (Başkan)	e-imzalıdır
Prof. Dr. Burak ASİLİSKENDER	e-imzalıdır
Prof. Dr. Evren MUTLUGÜN	e-imzalıdır
Doç. Dr. Üyesi Eyüp DOĞAN	e-imzalıdır
Doç. Dr. Üyesi Ahmet ÇOYMAK	e-imzalıdır

3.2 Informed Consent Form

Research Title: Extended Reality Technologies and Design Experience

Principal Investigator: Ayşegül Kıdık

Affiliation: Abdullah Gul University

You are invited to participate in a research study titled "Extended Reality Technologies and Design Experience" conducted by Ayşegül Kıdık from Abdullah Gul University. Before deciding whether or not to participate, it is essential that you understand the purpose, procedures, risks, and benefits associated with this study. The anticipated participation of students in the study will be changed between 3 and 27.

Purpose:

This study aims to investigate how the integration of Extended Reality (XR) technologies impacts the architectural design experiences of students. The study aims to explore the effectiveness and user experience of different design environments and tools, including conventional studios, screens, and VR headsets.

Procedures:

If you agree to participate, you will be asked to engage in the following activities:

- **Design Tasks:** On three separate days, you will be individually tasked with designing specific architectural projects using different design environments and tools (conventional studio, screens, and VR headsets).
- **Game:** On the second day before starting the design with screens in the XR environment, you will individually play a video game related to architectural education.
- **Surveys:** You will be asked to complete pre-survey, mid-survey, post-survey, and follow-up questionnaires.
- **Observations:** The researcher will observe your design experiences using an observation chart. The researcher will record these three days via a smartphone camera.
- **In-depth Interviews:** A one-on-one in-depth interview will be conducted with you after completing the design experiences. The researcher will interview via a smartphone camera.
- **Product Evaluations:** The researcher and/or voluntary design studio instructors will evaluate your design products.

Risks and Benefits:

Risks:

- There may be minimal risks associated with using XR technologies, such as potential discomfort or fatigue.
- Participation is voluntary, and you can withdraw at any time without consequences.

Benefits:

- Learn how to use a VR headset device for design.
- Learn how to use the Arkio Collaborative Design App.
- Engaging with emerging technologies in the design field.

Confidentiality:

All information collected during this study will be kept confidential. Your name and any identifying information will not be disclosed in any publications or reports resulting from this research. Data will be stored securely, and access will be restricted to the researcher and her dissertation advisor.

For the privacy of personal data, the data will be processed on the computer by removing personal information. The researcher will store raw data on a personal computer for five years. The researcher will keep the collected data and informed consent in a locked drawer. **There are no personal details in the raw data.**

Voluntary Participation:

Your participation in this study is entirely voluntary. You have the right to refuse to participate or withdraw from the study at any time without penalty or loss of benefits.

Additional Information:

If you have any questions or concerns about participating in the study, contact the Abdullah Gül University Ethics Committee (etik@agu.edu.tr) or the researcher. You can withdraw your consent for participation at any time without providing any reason. To revoke your consent, please get in touch with the research coordinator, Ayşegül Kıdık (aysegul.kidik@agu.edu.tr). Please keep a copy of this form that has been shared with you.

We appreciate your assistance and contributions to the advancement of scientific knowledge.

Consent:

I have read and understood the information provided in this consent form. I have had the opportunity to ask questions and have received satisfactory answers. I understand that participation in the research is voluntary, and I acknowledge that I can withdraw from the study at any time without providing any reason. By agreeing to participate, I voluntarily consent to take part in the "Extended Reality Technologies and Design Experience" study. I declare that I do not have any health issues that would pose a risk to participate in this research.

Participant’s Name: ______________________________ Date: _________________

Participant’s Consent: ☐

Researcher’s Confirmation:

I confirm that I have explained this study's nature, purpose, and potential risks and benefits to the participants and provided an opportunity for them to ask questions.

Researcher’s Name: ______________________________ Date: _________________

Researcher’s Consent: ____________________________

Ethical Committee Contact:

+90 352 224 88 00 - 02 - 03

etik@agu.edu.tr

AGU, Sumer Campus, B225, 38080, Kocasinan/Kayseri/Turkiye

3.3 Research Participation Announcement

Study Title: Extended Reality Technologies and Design Experience

Dear AGU School of Architecture Students,

I am excited to invite AGU School of Architecture students to participate in a groundbreaking research study titled "Extended Reality Technologies and Design Experience." This study, conducted by Ayşegül Kıdık from the AGU Institute of Science, aims to explore the impact of Extended Reality (XR) technologies on architectural design experiences.

Research Objectives:

- Investigate how XR technologies influence the architectural design process.
- Explore the effectiveness and user experience of different design environments and tools, including conventional studios, screens, and VR headsets.

Participant Eligibility:

We are looking for voluntary participants from the 2nd, 3rd, and 4th class levels in the Architecture department.

Selection Criteria:

A limited number of 3-21 students will be selected based on similar grades and levels. This study aims for a diverse representation of the School of Architecture.

Participation Benefits:

- Contribute to cutting-edge research in architectural design education.
- Reflect on your design skills and experiences.
- Learn how to use a VR headset device for design.
- Learn how to use the Arkio Collaborative Design App.
- Engaging with emerging technologies in the design field.
- Opportunity to explore XR technologies in a controlled and supportive environment.

Participation Process:

1. Selected students will attend an online (Zoom) information meeting.
2. Participants will be asked to complete a pre-survey.
3. Students will individually engage in design tasks over three days using different environments and tools (conventional studio, screens, and VR headsets).
4. Participants will fill out mid-survey and post-survey questionnaires.
5. An in-depth interview will be conducted after completing the design experiences.
6. The researcher and voluntary design studio instructors will evaluate design products.

Informed Consent:

Before participating, selected students will be invited to an information meeting. They will receive an online meeting link, and the researcher will present the study's details. After the information session, a consent form will be provided to the students for approval.

Important Dates:

- [Date]: Online Information Meeting
- [Dates]: Design Tasks (conventional studio, screens, VR headsets)
- [Dates]: Survey and Interview Sessions

Contact Information:

If you have any questions or concerns, please get in touch with Ayşegül Kıdık at the BA123 office or via aysegul.kidik@agu.edu.tr e-mail address.

I appreciate your interest and look forward to your valuable contributions to this research study!

Sincerely,

Ayşegül Kıdık
Lecturer/PhD Candidate
Architecture Department
Abdullah Gul University

Ethical Committee Contact:
+90 352 224 88 00 - 02 - 03
etik@agu.edu.tr
AGU, Sumer Campus, B225, 38080, Kocasinan/Kayseri/Turkiye

3.4 Pre-Survey Questions

1. Demographic Information:
   - Name or Nick Name:
   - Age:
   - Gender:
   - Academic Year: (2nd, 3rd, 4th)
   - e-mail address:
   - GSM:
2. Familiarity with Extended Reality (XR) Technologies:
   - How familiar are you with Extended Reality (XR) technologies? (Likert Scale)
     - Not Familiar at All
     - Slightly Familiar
     - Moderately Familiar
     - Very Familiar
     - Extremely Familiar
3. Familiarity with Virtual Reality (VR) Technologies:
   - How familiar are you with Virtual Reality (VR) technologies? (Likert Scale)
     - Not Familiar at All
     - Slightly Familiar
     - Moderately Familiar
     - Very Familiar
     - Extremely Familiar
4. Familiarity with Design Studio Tools:
   - How familiar are you with conventional design studio tools? (Likert Scale)
     - Not Familiar at All
     - Slightly Familiar
     - Moderately Familiar
     - Very Familiar
     - Extremely Familiar
5. Expectations from XR Technology in Design:
   - What are your expectations from using Extended Reality (XR) technologies in the design process?
6. Expectations from VR Technology in Design:
   - What are your expectations from using Virtual Reality (VR) technologies in the design process?
7. Initial Perceptions on Design Environments:
   - Before the design experience, how do you perceive the design process in a conventional studio environment?
8. Technology Access:
   - Do you have access to personal devices (smartphones, tablets, etc.) that can be used for XR experiences?
     - Yes
     - No

3.5 Mid-Survey Questions (Related to Video Game Experience):

1. Engagement with the Video Game:

- On a scale from 1 to 5, how engaged were you with the video game related to architectural education during the design process?
    - 1 (Not Engaged at All)
    - 2 (Slightly Engaged)
    - 3 (Moderately Engaged)
    - 4 (Very Engaged)
    - 5 (Extremely Engaged)

2. Effectiveness of the Video Game in Enhancing Understanding:

- To what extent do you believe the video game enhanced your understanding/learning of the built environment, different sites, architectural concepts, design samples, and structure systems?
    - Not at All
    - Slightly
    - Moderately
    - Very Much
    - Extremely

3. Connection to Design Process:

- How do you perceive the connection between the concepts explored in the video game and the design problems you were tasked with during the second day?
    - No Connection
    - Some Connection
    - Moderate Connection
    - Strong Connection
    - Very Strong Connection

4. Influence on Design Decision-Making:

- Did the video game experience influence your specific design decisions while designing the meeting hub (Y-named design problem)?
    - Yes
    - No
    - Not Sure

5. Interactive Learning Experience:

- Describe your experience using a video game in the design process. How did it contribute to your interactive learning experience?

6. Challenges and Benefits:

- Were any challenges or benefits associated with incorporating the video game element into the design process? Please elaborate.

7. Comparison with Conventional Learning Methods:

- Compare the effectiveness of the video game as an educational tool to more conventional learning methods you have experienced. Which do you find more beneficial, and why?

8. Suggestions for Improvement:

- Do you have any suggestions for improving the integration of educational video games in architectural design education?

3.6 Post-Survey Questions:

1. Overall Design Experience:

- Reflecting on all three design experiences (Conventional Studio, Screens, VR Headset), how would you rate your overall satisfaction?
  - Very Dissatisfied
  - Dissatisfied
  - Neutral
  - Satisfied
  - Very Satisfied

2. Process

- Which phase of the design process did you have challenges for each design experience? (analysis, synthesis, concept, initial design, design improvement, final design, representation) and why?

3. Preferred Design Environment:

- Which design environment (Conventional Studio, Screens, VR Headset) did you find most conducive to your design process, and why?

4. Innovation Impact:

- To what extent do you believe integrating Extended Reality (XR) technologies enhanced your ability to innovate in the design process?
  - Not at All
  - Slightly
  - Moderately
  - Very Much
  - Extremely

5. Collaboration Evaluation:

- Evaluate the collaborative aspects across all three design environments. How did each environment contribute to collaboration?

6. Comparison with Expectations:

- Reflect on your expectations before the study. How did the actual design experiences compare with your expectations?

7. Skill Development:

- Do you feel that your skills in architectural design have developed differently in each design environment? If so, please elaborate.

8. Challenges and Solutions:

- Identify your main challenges across all three design environments and suggest solutions. (Open-ended)

9. Preference for Future Design Processes:

- If given the choice for future design projects, which environment would you prefer to work in (Conventional Studio, Screens, VR Headset), and why?

10. Additional Comments:

- Share any additional comments or insights regarding your overall design experiences and the study in general. (Open-ended)

3.7 Follow-up Survey Questions:

1. Long-Term Impact:

- Reflecting on the design experiences one week later, how do you perceive the long-term impact of each design environment (Conventional Studio, Screens, VR Headset) on your architectural design skills and thinking?

2. Application of Learnings:

- Have you applied any insights or skills gained from the study to other design projects or coursework since completing the three design experiences?

3. Preference Persistence:

- Has your preference for a specific design environment (Conventional Studio, Screens, VR Headset) remained consistent, or have your preferences evolved over the past week?

4. Collaboration Insights:

- Looking back, what insights or lessons have you gained regarding collaborative design processes in the context of XR technologies?

5. Technological Adaptation:

After one week of reflection, How comfortable do you feel with integrating XR technologies in architectural design?

- Not Comfortable
- Somewhat Comfortable
- Comfortable
- Very Comfortable
- Extremely Comfortable

6. Design Workflow Changes:

- Have your design workflows or methodologies changed based on the experiences from this study? If so, in what ways?

7. Feedback on Feedback:

- Reflect on the feedback provided on your design products. How helpful was the feedback, and did it influence your subsequent design work?

8. Recommendations:

- Do you have any recommendations for improving the study or suggestions for future research in this area?

9. Future Involvement:

- Would you be interested in participating in future studies or projects that explore the intersection of architectural design and emerging technologies?

10. Additional Comments:

- Share any additional comments, insights, or reflections that you think are relevant after one week of completing the study. (Open-ended)

3.8 Observations

Observation Chart:

STUDENT NAME:	
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)						
- Interaction with environment (1-5)						
- Interaction with tools (1-5)						
- Interaction with peers (1-5)						
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)						
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)						
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)						
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)						
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)						
- Presentation Studies Efficiency (1-5)						
CHALLENGES						
- Using Tools Challenges (1-5)						
- Engaging Environment Challenges (1-5)						
- Design Challenges (1-5)						
- Design Process Challenges (1-5)						
- Student Motivation Challenges (1-5)						
RESEARCHER NOTES:						

4. Case Study Materials - Raw Data

Students are coded as ST-1, ST-2, ST-3, ST-4, ST-6, ST-7, ST-8, ST-9, ST-10, ST-11.

4.1 Consent Form Answers

Consent:
I have read and understood the information provided in this consent form. I have had the opportunity to ask questions and have received satisfactory answers. I understand that participation in the research is voluntary, and I acknowledge that I can withdraw from the study at any time without providing any reason. By agreeing to participate, I voluntarily consent to take part in the "Extended Reality Technologies and Design Experience" study. I declare that I do not have any health issues that would pose a risk to participating in this research.
Participant consent:

ST-10	I agree	4.9.2024
ST-2	I agree	4.8.2024
ST-1	I agree	4.8.2024
ST-6	I agree	4.8.2024
ST-3	I agree	4.8.2024
ST-9	I agree	4.4.2024
ST-4	I agree	4.8.2024
ST-8	I agree	4.8.2024
ST-5	I agree	4.8.2024
ST-11	I agree	4.9.2024
ST-7	I agree	4.9.2024

4.2 Pre-Survey Answers

ST	Q-7	Q-8	Q-9	Q-10	Q-11	Q-12	Q-13
ST-3	Not Familiar at all	Not Familiar at all	Moderately Familiar	To strengthen my different perceptions	To strengthen my different perceptions	Conventional design tools allow us to do our job, but I think we now need to use our different perceptions with different technologies.	Yes
ST-10	Not Familiar at all	Slightly Familiar	Slightly Familiar	To understand the use of XR tech in design processes in terms of concepts, trials and approaches	To visualize the building scale in human eye and reality	It makes the studio more real and understandable	Yes
ST-2	Not Familiar at all	Not Familiar at all	Not Familiar at all	i believe that using new technics while designing a space will give you new visions and idea so using xr technologies will give me new ideas	This will be the first time for me to use VR while designing i think it will be helpful for me to understand space more efficiently	sometimes i stuck in some idea because being in same spaces every time not helpful for me	Yes
ST-6	Not Familiar at all	Not Familiar at all	Very Familiar	in order to make process easy and more livable, to take benefit.	to increase reality, virtual reality is so important especially for design process in terms of creating idea part, and to build in real. to improve understanding the process it can be beneficial.	actually, ıt can be difficulties in terms of process. Because design process has no rules. That's why sometimes imaging something can be problematic in terms of passing through to applying part.	Yes
ST-9	Slightly Familiar	Slightly Familiar	Extremely Familiar	Project can be tested in the real-life before constructing and in the phase of construction it can be good tool to communicate with workers.	To see, test and develop design at every stage of the project with every details.	Important think is designing and developing projects and it can be done with different tools from primitive tools (like hand sketching with paper and pen) to software.	No
ST-1	Not Familiar at all	Not Familiar at all	Moderately Famili ar	especially understanding the basic mentality of these tools and how can we interact or how they are interacting with the architectural approaches.	Tbh I don't separate the programs or their purpose for architectural approach so My answer will be the same with the one before	The traditional studio design process is all about finding a way of flow that we can capture in the flow and then continue. First, we use our minds and eyes according to the way we perceive life and the environment through a subject and area, and then we express or express this through paper and drawing processes. In order to better perceive the 2D dimension that emerges as a result of this expression and to fit it into a certain form and volume, we engage in ongoing model-making experiments. I say experiment because I think this process is empirical. We use digital modeling to design the abstract mass that emerges as a result of this process in real life, and we complete the studio process with the presentation and persuasion process. The traditional studio is an important area where physical, mental and emotional empowerment can be achieved at the same time, especially when these processes are progressed in a healthy way.	Yes

ST-8	Slightly Familiar	Slightly Familiar	Extremely Familiar	The chance to experience many details of the design at the same time, more easily and in a shorter time, and to be able to explain the design to others more easily.	It is a good opportunity for easier and more realistic results and will give a different perspective., Most importantly, to experience the design at its own scale.	My design works done using normal methods not only provide new design products but also the ability to think with hands. I think this is a very important ability to take design to a further level.	Yes
ST-4	Slightly Familiar	Moderately F amiliar	Very Familiar	I am expecting to take my first step into XR technologies for my department and career by learning and enjoying	I am expecting to take my first step into VR technologies for my department and career by learning and enjoying	I think the design process in the traditional studio process is inefficient and incomplete, apart from verbal feedback. I believe that it would be more beneficial to support the studio with such different experiences that will open our horizons and pave the way for different designs and innovations as architecture students.	Yes
ST-5	Not Familiar at all	Not Familiar at all	Very Familiar	I expect to be able to visualize designs more realistically and detect errors more easily	I expect to be able to visualize designs more realistically and detect errors more easily	I have a hard time visualizing the 3D shape when imagining it, and I think more in 2D before making a model.	Yes
ST-11	Not Familiar at all	Slightly Familiar	Not Familiar at all	XR are combined VR, AR and MR. For Design process it can help understand design, before construction.	It is provided 360 full screens; VR give more open perspective.	Classical ways, generally laptops trying to 3D design on display 2D screen.	Yes
ST-7	Not Familiar at all	Not Familiar at all	Very Familiar	I don't have enough information on the subject. Therefore, I do not have any expectations yet. But, I'm curious about XR technologies. I would like to know what kind of opportunities it offers, especially in the design.	I think, VR will help me understand the design better in the 3D.	When we are in the design process in a conventional studio environment, our primary goal is to express our dreams and thoughts. Then, our design is revised for continuous improvement, thanks to feedback or discussion environments with our friends. The process repeats like this.	Yes

4.3 Mid-Survey Answers

ST	Q-2	Q-3	Q-4	Q-5	Q-6
ST-3	Very Engaged	Moderately Engaged	moderate connection	No	The sketches were nice, but I think they should be more integrated into the game. Walking on the street and entering the maze and seeing only the drawings did not impress me much.
ST-4	Very Engaged	Moderately Engaged	strong connection	Yes	Being able to see some important architectural structures simultaneously during the design process contributed to broadening my horizons and gaining inspiration.
ST-11	Moderately Engaged	Moderately Engaged	strong connection	Not sure	The video game was useful to understand the perception of space. Taking human dimensions and movements between spaces was useful in understanding scale when designing spaces and spaces.
ST-8	Moderately Engaged	Moderately Engaged	some connection	Yes	It was more useful to use it beforehand to create a digital perception while playing digital. In other words, having a digital perception before starting a digital design helped me understand the design.
ST-9	Moderately Engaged	Moderately Engaged	some connection	No	While playing the video game it helps to moderate the screen while designing to get used to the digital environment to design with it
ST-6	Very Engaged	Moderately Engaged	strong connection	Not sure	Getting used to the environment with a video game before starting the design process allowed me to have a much more efficient design process. In order to use technological environment and control the perspectives.
ST-7	Not Engaged at all	Slightly Engaged	no connection	No	I think that being in a labyrinth independent of the city actually makes it difficult for us to perceive the city. Because my only goal while playing the game was to enter the maze and complete the task. Also, I don't think he has the ability to influence the design process in his assigned duties. If the purpose and content of the game were to solve any problem in the city, I could perceive the city better. because my goal would be to find that problem and the solution to that problem. Or if the tasks given in the maze were about designing the maze and getting out of it, it could affect our design process.
ST-5	Very Engaged	Moderately Engaged	moderate connection	Not sure	The matching part was really catchy, but finding the pictures in the first part could be improved a little more because it can be found without seeing the pictures and requires less effort.
ST-10	Moderately Engaged	Very Engaged	moderate connection	No	While exams and tests take us only so far in understanding who built what structures with what materials or structural systems, games do provide a tutorial field where we can explore. These games serve as an entertaining and educational platform. They offer a space beyond traditional assessments, allowing us to engage in hands-on exploration and learning.
ST-2	Moderately Engaged	Moderately Engaged	some connection	Not sure	I think video games would be a good method in the field of architecture. After all, every game has a world that is sometimes realistic and sometimes utopian, and I think this can be used to develop creativity and identify problems in different situations.
ST-1	Extremely Engaged	Slightly Engaged	some connection	No	It was a good game but the main problem about this game even though the architectural context is trying to use in it but the architectural idea is vanishing in the game so it does not affect me very well. But for the second game it is really beneficial to understand the scale and comfort of the areas.

ST	Q-7	Q-8	Q-9
ST-3	did not provide any benefit	The three-dimensional perception of the game can contribute to the design process. Experiencing a city through a game can be a different experience.	Famous architectural structures can be experienced in 3D rather than remaining as sketches.
ST-4	Although it was difficult when starting the game, I started to see the benefits as the process progressed and I got more familiar with it.	Since different spaces are presented to us in the game, these awaken different possibilities in our minds and strengthen our design ideas, while I think classical design techniques limit our minds.	I believe that it would be beneficial to improve the obstacles in the game and to give courses on such content in architecture faculties.
ST-11	The lack of organic structures in the game and constant horizontal movement can cause difficulties in holistic design.	More conventional training feels freer in terms of design, so it is more efficient, but this is because the restrictions in the video game can be more useful if a more flexible workspace can be created.	If a more realistic and comfortable working environment is created in the game, organic shapes and a more realistic perception of space and structure, the more efficient the designs can be.
ST-8	It was quite difficult to understand the mobility at most while using it.	There is an advantage that video games provide to people in terms of perception and some features seem easy to use. However, since the beginning of digital design is hand and brain coordination, I do not think that it is aimed at improving one's design skills. The most important advantage of digital applications is their convenience in terms of external interactive features. But the use of digital assistants when designing can also have a restrictive effect because it depends on the ability to use it.	In terms of the content if it is designed well, it would be helpful tool in the design process. But it should be well organized.
ST-9	Yes, video game prepares me to the digital rotation to design with those tools. But in video game there can be some exercises like move, rotate, copy to pass game levels and then ı can be much more familiar with these tools while designing my project after the video game.	What I experienced is that it helps to moderate around the screen to be part of the design environment and also with the level kind of system in video it can help to get used to those tools step by step.	According to the next aim it can be planned to improve adaptation to digital tools. Like game can be planned to learn tools like how to create shapes how to extrude shapes how to orient kind of skills can be introduced and the levels of it can be developed step by step.
ST-6	The movement capacity in the game was low, so 360-degree management and vision were causing problems. It actually looked like it was stuck between 2D and 3D. That's why for this way it looks lie traditional 3d programs.	actually, it can be beneficial for 1st grade to dream something 3d. But as ı said it should develop more in terms of view and perspectives. However, it can be restrictive for the first phase of design. Because sometimes sketches, hand drawings have more chance to free working and imaging.	I believe that 3D perception and environment and perspective management should be improved. There is a perception that it is controlled by mouse or hand and that there is a limited perspective.

ST-7	It was a game that made me understand again the difficulty of walking on a rough road and the importance of pedestrian paths.	Video games are a useful method in our education process, but I think the purpose of the game is important. For example, Minecraft is a game where we can make designs and have an idea about the materials, although they are limited. Making designs independent of school and reality improved me. And playing Minecraft was actually a game that made my design process enjoyable and increased my computer usage to a certain level. I think such games should be used as educational tools.	Games that will improve our design direction can be played as an elective course.
ST-5	It might be more effective if we did the tasks we did in the labyrinth in the city.	If the video game is developed and requires more attention, it may be more effective than the other method.	Quests can be done within the city
ST-10	Viewed as a benefit, it provides an opportunity to explore not just the visible aspect of a space, but also its interior. However, looking at it as challenges, we might find ourselves confined within the limits of the game's capabilities. In other words, we may be thinking or accepting only as much as the game presents to us. For this reason, I believe either the boundaries of the game need to be greatly expanded or the game itself should evolve.	Video games offer a unique perspective in this regard, emphasizing a more informal approach to education rather than alternative educational methods or conventional methods. In fact, they can create a fun competitive environment that enhances learning.	If a game is designed for architectural design purposes, it should encompass various architectural approaches. For instance, the game design could allow for organic design, not just limited to squares or triangles, but even shapes that can morph parametrically. "The Forgotten City" game, for example, where the architectural and artistic understandings of different cultures are somewhat highlighted. While the game is set in the past, in a future iteration, optional information about past designs and approaches could be provided, perhaps even in a modern setting.
ST-2	Video games can have a positive impact on the design process, but these games must be considered in great detail. It should be realistic enough not to disconnect from reality, yet utopian enough to nurture creativity. Considering that each design is unique and different, it would be meaningless to think that a single game or type of game will help in the design process. For this reason, multiple games should be designed to aid the design process.	I think video games can be an effective tool in architectural education, not only in the design process but also in courses such as history and building. For instance, the fact that focusing on video games is easier than focusing on some courses can increase the efficiency of the course in case of using them.	While games can be an effective tool, they can also be a reason for distraction, so the game needs to be designed in great detail and without too much stimulation.
ST-1	Maybe to understand the logics of the games at the beginning was a little bit hard. Tbh if there was no instructor It would be probably really difficult for me to make a process.	the second one is more conventional to understand the logic and basics of architectural programming and learning.	Maybe a game which would be directly related to architecture not a game that uses it as a tool to reach audience.

4.4 Post-Survey Answers

ST	Q-2	Q-3	Q-4	Q-5
ST-3	Very satisfied	The first stage is not too difficult since I am familiar with it. It was a comfortable design process after getting used to the application in the second stage. It was very difficult to learn the VR device at the last stage, but after I got used to the system, I had a much more comfortable process compared to the other stages.	The first stage was very comfortable to design. The vr phase was also very easy when assembling the components. Additionally, being able to experience the inside of the design was a different and effective experience.	Extremely
ST-4	Very satisfied	I encountered certain difficulties at every stage. Before I started using the programs, I had problems because I did not know how to use them, but as I tinkered with them, I learned and discovered that the design process was shortened and more efficient results were produced.	I found VR headset more useful and convenient because I could easily scale the area we wanted to design and design comfortably from every angle.	Very much
ST-8	Satisfied	The first design-form relationship can be quite difficult because in this part, it is necessary to proceed by thinking both abstractly and realistically, on a high scale and on a human scale, which results in working on multiple layers at the same time. Therefore, it may be good to have experience at different scales with the help of technology.	Every environment has its own way of perception, it is difficult to say that any one is better than the other. But I think seeing the design in every environment will allow you to look at it from different perspectives and understand the design more accurately.	Very much
ST-9	Satisfied	While designing in screen (tablet) it was hard to navigate and design. But with VR it was much easier design with 3d tools to design in a much more detailed way needs time and experience.	Conventional studio was good to start design process but I believe VR was much more efficient because lots of data in the scene while designing and easy to understand environment to get influence by them.	Very much
ST-10	Very satisfied	The most challenging part for me is the design improvement stage. When spaces and plots are already determined, it can be difficult to draw them architecturally and see their harmony, let alone identify errors at this stage.	Working on a design on a tablet was the most challenging and time-consuming aspect for me, especially since I was dealing with creating a detailed model. However, if I had approached it as a tool to simply demonstrate spatial relationships in the concept or initial design stage, it could have provided more opportunities for visualization. Through VR, I realized that being able to see and experience the designed space directly in a 1:1 scale offers a clearer understanding of the design. In conventional design, on the other hand, we can quickly sketch and take notes to remember our ideas since it's a familiar learning environment. I believe each environment has its own unique advantage.	Extremely
ST-5	Satisfied	Design improvement because the implementation felt inadequate.	VR headset but a more advanced application should have been used because I couldn't use the axles properly and it would have been better if there was a tool with which I could draw lines instead of drawing walls or windows directly.	Very much

ST-6	Very satisfied	in first phase with traditional one, I didn't have any difficulties for representing the design idea. Because ı can draw what ı want and it was really quick method. However, making sketch has an individual representing style. That's why maybe it can be problematic to transfer the idea and 3d version. For second phase. I really love the program. Because it was between 3d program and sketch board. There were lots of chance to make design and see in real life. But according to my mind, there were missing command and behaviors. For some reason which ı don't know, program didn't let us change some settings. It has to develop. It was like first phase of that program. We can use for some exercise. But we cannot carry forward our design in this program. For third phase with VR headset. I had challenges for design improvement. As ı said program don't let me to change something. But feeling myself in that world was amazing. But ı think there were some scale and area problem.	to be honest, ı was just familiar with conventional studio before attending this activity. With 0 knowledge then just a few days practice, I thought VR headset can adapted to our design process. But actually, for feeling comfort, screens maybe can better choice. Because VR headset was not ergonomic especially for long hours.	Extremely
ST-11	Satisfied	Design improvement part is hard because when you complete initial design, starting to real form the structure is difficult	All of them are useful the process. Specially understanding the all area and the relationship between close environment are very good using these technologies.	Extremely
ST-7	Very satisfied	In general, making a hub challenged me in terms of scale. I think minimal and practical design limited me. Since I worked with conventional method programs that I was used to, I did not have any difficulty in using the program. But learning a new application for the screens method and doing it from a tablet was difficult. I was very comfortable working with VR glasses because I was more familiar with the application and tried to design without worrying about the scale.	Since I am used to the conventional studio method, it is more effective when designing, but I think I can make the three-dimensional thinking problem I experience there easier with VR. After transferring my thoughts to the sketch, I can see what effect it has in three dimensions more easily and enjoyably with the VR method.	Extremely
ST-1	Very satisfied	Understanding how the technologies work was difficult for me because It was a new technology for me to understand it.	VR headset was really helpful for me to understand the design idea and how it works tbh. But I believe that it was lack of creativity So I believe mixing conventional studio and VR set would be helpful.	Extremely
ST-2	Satisfied	Since each design is unique, which step I have difficulty with during the design process may vary. But the step that I have difficulty with in all of them is generally the presentation stage.	I think using VR and traditional studio together will make the design process easier and make the designs more innovative. For example, continuing sketching etc. using pencil and paper prevents creativity from taking shape according to the limits of any application. VR helps improve the design by seeing what is on paper in real size.	Moderately

	Q-6	Q-7	Q-8
ST-3	The first two stages were not very conducive to collaboration. But by using VR technology, it is more possible to let other people experience the design and get feedback.	Using VR technology scared me a little at first. Because I don't know how to use devices. I was wondering how much of an impact it could have. But after experiencing it, my ideas changed and I found it much more useful.	The first stage felt normal because it was a process I was used to. The second and final stages were an interesting experience. It allowed me to discover design skills I didn't have. It allowed me to go into three dimensions and see the design better and notice the details. The only problem was that the application used was not suitable for organic-like designs.
ST-4	Since we were working on the same scales, building different concepts on an area I had worked on before supported the design process.	I thought it would take more time and be difficult to learn. It was easier and more enjoyable than I expected	I discovered that I can look from different angles in every different environment.
ST-8	Doing the design in the first conventional environment in the way I was accustomed to made it easier for me to develop different variations. Designing with Ar helped me understand scalar changes more easily. As someone with little spatial experience, VR enabled me to more easily understand what the project has become and its shortcomings through faster approaches to the project.	I didn't know the device very well and had no idea how it interacted with the environment. but after designing it, I understood how he understood the space. Understanding this helped me relate to design more easily.	Of course, it has changed and evolved because it helps me understand in different environments and with different tools. This way I can communicate with the different stages of the design. For example, if I have a problem with form and human scale, I can understand it very easily, solve it with other environments such as conventional, and then go back to the VR environment. This gives me a more realistic design experience
ST-9	Screens do not well with me but it has one advantage is that you can carry anywhere and design anywhere silently. VR experience is the best because of you are exactly in the design and environment of it. Conventional studio is must because of it gives first glimpses about design decisions. Also, it can be enhanced with VR experience.	I was thinking that VR tools is much broader to design but it limited me maybe because of the software that I used or not familiar with those tools or time that I spend is not enough. So, I was thinking that I can design much more fluid forms or tools are vary but it was too limited.	I am used to designing with sketches and then with the computer but I realized that VR can enhance my design development for each phase for example it can show my interior material choice in an efficient way (but what tool that I use is not enough) or can give understanding of scale of my design in the first phase of the design.
ST-10	Each design environment has its own set of conveniences and challenges. However, by utilizing all these environments, the difficulties encountered in design can be overcome. For instance, traditional methods allow for ideas to be quickly jotted down and sketches to be produced. A diagram illustrating the relationships between spaces can be created on a tablet and used to explain the spatial layout. Later on in the design process, VR can be considered as a one-to-one solution for visualizing and designing the space.	As soon as I tried it, I realized that it was beyond the experience I expected. Frankly, I've never worn VR before and I didn't expect it to affect me this much. Especially in terms of understanding the size of the space, everything can be understood with the human scale.	Yes, I believe it's an improvement. Sketches made to illustrate ideas can be difficult for others to understand since they are quick and often in a style that only the drawer can decipher. However, an application creates a universal language that can be understood by everyone involved.
ST-5	They may all have different ways of using them and I think they should be used together.	It was a little harder than I expected	No because I don't think the application is efficient

ST-6	to create something from zero level in screens and VR headset, was difficult especially for huge designs. Because in some part program don’t let you to arrange something according to yourself.	I was scared a little bit actually in order not to manage the process. Because ı was a lover for free hand drawing. I'm not be able to produce products in pc or technological environments. But after the study, just in an hour ı really get used to control the commands.	Actually, for now no, because if we are waiting kind of skill improvement we should be integrated for whole process. I mean the analysis, concept, form finding, making programs then design. But in terms of representation style, it improved for the first phase actually.
ST-11	Exploring the field on a human scale at the beginning of the design directly affects the design process positively. On a larger scale, it was more useful to see and experience environmental connections. However, the entire process is not suitable for design because there is a restrictive form of application, it is at the design stage of the structure. It is also easy to transfer it to this area using other 3D applications.	Since I had not had the opportunity to experience this technology before, I thought I would have difficulty getting started, but since the interface was simple, it was easy to explore and learn.	It definitely added more things to my own experiences in the design process. I was inclined towards a more conventional design, but thanks to this technology, I had a different perspective.
ST-7	The conventional method is an effective method where we can exchange ideas together. I don't think the screen method will be successful in this regard. I think it will be effective to visit each other's designs using the VR method and show the recommendations quickly through VR.	The ability to easily transfer my thoughts to three dimensions met my expectations. But the fact that the glasses were not ergonomic was unexpected.	After improving our design skills by playing games, we can transfer our design as a basic method using the conventional method and develop it quickly with VR glasses.
ST-1	each design environment offers unique advantages and challenges for collaboration. Physical environments excel in immediate feedback and spontaneous ideation but are limited by geographical constraints. Virtual environments enable asynchronous collaboration and easy file sharing but may lack the richness of face-to-face interaction. Hybrid environments strive to combine the best of both worlds but require careful management to ensure seamless integration and inclusivity.	I was expecting to be more difficult to learn it but it was really easy for me to use it.	Yes, especially for designing and modelling in such programs now I believe that I can take that further and make my models easily with my tablet and other programs.
ST-2	In my opinion conventional studio is the least effective one for collaboration out of three. VR and screen would be more effectual in case of everyone can make changes at the same time in design.	Actually, I thought the application would be more comprehensive with a simple interface. But even though the interface is simple, I think it needs to be improved. I didn't really think that video games could have a clear impact on architectural education. But I now think that it can be an effective tool if developed ideally. I think tablets and VR will be more effective in the development of designs.	I think it has evolved as I think each method will be more effective in different areas of design.

	Q-9	Q-10	Q-11
ST-3	The difficulty in the first stage was that I could not feel the design and details well enough. In the second stage, I was not able to perform commands such as rotating and turning on the iPad. At the last stage, the difficulty was not knowing what to do due to using VR glasses and controllers for the first time.	I would like to use the VR headset again in the design processes. The chance to experience the scale of the design on a true scale was very impressive. I will also include the opportunity to quickly design from an iPad into my design process.	It was my pleasure to participate in the study. Thanks to this study, I had the chance to try a opportunity that I could not have obtained. It changed my perspective on design and technology. I didn't think it would replace the conventional style until I experienced it. It was an eye-opening process. And it was definitely a work that I think should be used in design studios.
ST-4	I don't think I have any serious difficulties.	I prefer to use VR Headset. I think it is more practical and comfortable	It was an enjoyable process. If there is a similar training or program, I would like to participate
ST-8	understanding the tools, we used in each design environments. Before starting the design with VR or AR people should have experiences with the devices. otherwise, it will limit the design skills	VR because it is more easy to use and understand more.	Experiencing all the processes was a very helpful point. I think this helps us understand more easily. I think that when the contents of these experiences are studied and organized, they can be more open to new skills and develop.
ST-9	Conventional studio is what I am used to doing to produce or to present my design I am searching for new tools. For the screen (tablet) I am not quite relaxing with it most probably because of I am not familiar with it but in any case, it does not contribute to my design process so much not new perspectives contribute to me. VR experience is great because I can feel myself inside the design environment. I can be part of it, with it is easy to dream and design with it.	VR Headset. I can feel part of the design and I can navigate around it easily, and I can get environment data (like how tall buildings are around my plot) in place.	VR headsets can be involved in each phase of the project to test the design in that view get feedback and continue to develop the design according to that new feedback. It was good to experience all the tools to know to use in future projects.
ST-10	In conventional design, clarity is key, while speed is crucial in a tablet environment, and modeling takes precedence in VR. For conventional design, using a universal language or sketching with a more distinct style could be solutions. It's truly challenging to achieve both speed and detailed modeling in a tablet environment; for example, moving and scaling a model can be time-consuming and cumbersome. I also believe that prolonged use of VR could lead to headaches. Additionally, the design needs to be somehow translated into this medium, but I'm unsure how that would happen.	I believe VR would probably be the better option. With advancing technologies, experiencing a space firsthand through VR seems to be the most effective way. If we consider that our designs are essentially a form of marketing, we can say that experience is crucial for marketing. Additionally, considering there is also rendering involved in VR, I think it will become a commonly used tool in the future.	I believe that education has changed with time and technology. In the past, there were spaces with drawing tables where architects gathered, but recently, drawing and modeling together on computers have become possible, and now it's even possible to do this in a different reality. This suggests that this advancement will continue to be used in the future. The ability to quickly transfer ideas and imagination with technology also accelerates this progress.
ST-5	I had difficulty adjusting the angle properly	VR headset because it will be useful for people like me who have difficulty thinking about design in 3D.	I think the applications that can be used in VR should be increased and developed further.

ST-6	For conventional environment, thinking and creating new things were easy but representation can take time and had difficulties to represent in 3d with drawing. Then for screen and tablets, representation style was okey, the program language was easy no complicated. But ı think it should improve in terms of command. Because it was like demo. And as architecture students we get used to use some command such as copy paste like our arm and hand. The third environment which is VR headset to control something with your body was so good but this is not ergonomic and it had difficulties about again program and command.	actually, during the process ı prefer screens and conventional ways together. But the final product especially representation phase of our design, ı definitely prefer the VR headsets.	ı shared my all opinion in other questions
ST-11	The difficulty lies in shaping the design, but I can solve this with the support of other programs. Design experience increases by saving files with obj extension.	I think all areas should be used together. They all benefit the process.	By combining conventional training with this technology, I gained a different perspective on the entire process.
ST-7	I had difficulty in conveying my design clearly in the conventional studio method. A solution may be the necessity of working together in plan and three dimensions. It was very difficult for me to make it three-dimensional on the tablet with the screen's method. But it helped me learn the program by tinkering with it. However, the program used can be improved so that we can use it on a tablet without difficulty. I think the difficulties in the VR method are only physical pain.	I think all three methods should be used together because I think they complement each other's shortcomings.	During my design process, I always try to walk around my space by imagining it, and sometimes I can get disconnected from reality, so I feel like I've imagined a design that won't come true, and it's an emotionally upsetting situation. However, the feeling of transferring my design to virtual reality and walking around in it actually helped me a lot in what I wanted to do." For this and other reasons I have stated, I think the virtual reality method should be used in design studios. In addition, the program we use needs to be improved. It is very inadequate, especially for organic studies, and the tools used need to be diversified.
ST-1	I did not have main design problems tbh but maybe I can say that the lack of program's diversity limits the design interpretation.	VR headset because it is really easy to manage and u look like u are doing it really.	I believe that especially using VR with our traditional design studio environment would increase the efficiency of and the effect of our project very well. Not that but integrating with tablet and then transferring to our comp creates a good work process I believe.
ST-2	The main problem I had with the screen was that I couldn't get used to the application, so I don't think it was very efficient. I progressed more easily in the traditional studio because it was the methods and tools, I was familiar with. Although I had difficulty in VR at first, it became easier to work since the same program on the screen as I got used to it.	I don't think the screen is a very different method from the traditional studio, so video games, traditional studio and VR would be the methods I would choose.	It is now clear that technology has an important place in our lives and provides convenience in many professional fields, and I think architecture is one of the fields where technology can be used most efficiently. For this experience, I don't think the video game and application we use is enough.

4.5 Follow-Up Survey Answers

	Q1	Q3	Q3	Q4
ST-1	Frankly, my interest in digital has increased even more. If I had a VR headset now, I would want to experience VR by transferring my design directly.	No at the moment, but I would like to do a project that involves VR and the glasses operation of an application, especially in a project related to urban planning, which is my own idea.	Actually, I can say it changed I can say that a studio which includes both would be better for me right now.	As someone who does not understand technology, getting used to something that I did not think I could get used to very quickly made me think that it was actually easy in terms of applicability and experience, but then I think that its constant use will cause physical health defects and problems.
ST-9	Conventional studio is what I am used to so that will continue for each phase of my project for sure. Tablet is not work me it just makes my process slower so I will not continue with that. I am planning to insert VR headset to each phase of my personal project because it helps to what I want to create.	For now, no, because I need to gain some technical knowledge after that for sure I will be applying those tools to present my design.	No, my choice is the same, Conventional processes and VR headsets will be involved and they will promote each other.	While experiencing my design process with the VR headset it can give me much more reality so I can observe and develop my design in each phase of my project. For just test it out.
ST-10	In a conventional design environment, I believe that enriching my design with technology would actually enhance its expression and make it more comprehensible. It would bring a different perspective to the design, making it more accessible. Providing an environment where the intended idea can be presented in different ways, our design approach can be varied. This, in turn, brings a different perspective to our design.	I would have liked to implement it, especially experiencing it with VR goggles for spatial perception. Additionally, having a tablet environment where I could quickly convey my ideas and make adjustments comfortably would have been more understandable and practical. However, I haven't been able to implement it, yet.	I believe that all three different systems should progress together; this would provide diversity and ensure better understanding through different perspectives. Although I struggle with the tablet environment, I believe that with practice, I can gain and improve this skill over time.	I believe that designs made in these environments could be more consistent because they can be quickly integrated into reality, and the space can be experienced. It doesn't just stay on the screen; it also provides the opportunity to see it with your own eyes.
ST-4	During my design process, I discovered that I used more creative methods by looking at a broader framework, thanks to the methods we used.	yes.	My preference has not changed	I am not sure

ST-6	to be honest, ı tried to integrate screen to my design process. it helped in some way to represent my idea.	Actually, for screens and tablets, ı used for 3d form finding. But in terms of drawbacks of application. ı couldn't continue on that way.	ı still feel more comfortable in conventional studio, but trying those process is also getting easier for screens. but normally ı don't have chance to reach VR headset.	actually, being inside of design with real scale was amazing. And it improves the understanding of design.
ST-5	I think it will be easier if you start with conventional and supported with a VR headset.	For now, no	My opinions from previous polls are still valid.	Actually, I felt that we were free while designing because our dreams are usually limited to what we see, but I think we can be freer with XR technology.
ST-2	While screen and VR are nice experiences, I don't think I've experienced enough to make a long-lasting impact for my design skills and perspective.	While I was experimenting, I realized that I was having difficulty designing in a short time and in a practical way. For this reason, I'm trying to think more practically now.	I usually used sketches and models during the design process. But recently I sometimes added the screen to it. I don't have VR, but even if I did, I would probably use it while I was developing, not when I started designing.	Regardless of whether it is sufficient or not at the moment, I thought that design would be more intimate with this technology in the future. For this reason, I need to improve myself more in terms of technology.
ST-8	Generally, nothing much has changed, but I realized that when I was designing, I was thinking about what it would look like in the VR environment. The thought arose of how I could explain the project with this technology. Because with every skill we learn, we think about how we can connect it. For example, if you have just started learning modeling, you can learn how to make better and easier models while designing. Or if we have just started rendering, we think about what kind of relationship between materials and space would be better. Having this experience gave me the foresight to see this in that environment.	I haven't implemented it yet, but I have a process in mind to implement it. It helped me develop some design and presentation ideas	I agree with last week. I have an opinion that using it will be beneficial, but a one-sided design focus will weaken the design.	I looked at some application styles in general and thought about how I could include some applications in the presentation and design process.

ST-3	The conventional studio started to feel more boring in the creation process. When compared, the other two methods seem more practical and innovative.	I continue to use the application we use on the iPad.	I realized again how easy it is to design with screens and VR glasses in the conventional studio process, and I felt what was missing.	In addition to teaching something different experientially, XR technologies showed that the traditional design process will move to more technological dimensions.
ST-7	Thanks to the conventional method, I realized that I needed to increase my practical thinking skills and I am currently working on this. Thanks to the tablet, I can make three-dimensional sketches and this improves my three-dimensional thinking skills. Thanks to VR, I try to design by traveling around the area. What I mean is that I gained the ability to design by thinking as if I were walking in each room (I'm not very good yet, but I'm trying :))	yes	My preference has not changed.	During my current education process, I am having a hard time perceiving the area fully. I sometimes think that if there was VR, I could place the area clearly. I dream of designing in a way that we can navigate the land in street view, rather than in the application we currently use.
ST-11	Frankly, there was no big change, but I wanted these technologies to better understand spatial perception at the design point.	It didn't leave such a difference on me. New projects continued as usual.	In addition to the usual studio, I wanted to use VR glasses for the design process.	Design should start with the usual method and should be developed in the XR environment

ST	**Q5**	**Q6**	**Q7**
ST-1	Very comfortable	Frankly, I do not believe that a 1-week period is sufficient for this, so I cannot say anything definite.	Frankly, as I said again, it may be too early to say this, but I believe that with the continuity of such an image in terms of designing and using VR, I will be more self-confident and forward-thinking in my designs.
ST-9	Neither comfortable nor uncomfortable	Actually yes, just I need to prepare my project to bake in a VR environment.	Yes, it influences apart from the screen part. I am planning to insert VR headset into my design development to test it out.
ST-10	Very comfortable	Unfortunately, due to the lack of access to adequate technology (due to economic reasons), this didn't change. However, if I could have access to it, I would probably work in more hybrid ways. While choosing between tablet and traditional methods for design and sketching, I would choose VR environments for modeling and understanding space. This way, I wouldn't just rely on thinking and imagining, but I would also have a visual and sensory understanding by seeing and experiencing it.	Yes, actually, it did influence me. Since it was my first experience, I approached it with a bit of skepticism, but with the encouragement of the instructor and my own curiosity, I was able to explore the applications and test their capabilities. As a result, I was able to move away from a conventional understanding and create my own interpretations in certain areas.
ST-4	Somewhat comfortable	did not change	I think my designs have become better by changing my design and methods in line with the feedback I receive.
ST-6	Somewhat comfortable	actually, for now it didn’t change completely because of couldn’t integrate this technology	for form finding it helped a lot. but It should not be denied that a real physical model also can help more.
ST-5	Very comfortable	I can't say that it has changed much because I could not integrate them since the course process was the same.	I do not know
ST-2	Neither comfortable nor uncomfortable	I just decided to add on-screen modeling to my design process. I usually used it when i present my design before.	Frankly, I wasn't very happy with my designs. Because I was new to both the method and the program, it was difficult for me to adapt.
ST-8	Somewhat comfortable	While designing, I started to think about my narrative abilities in that technology. If my knowledge of the design process was insufficient, I started to look at how I could improve it.	I realized that I needed to equalize my digital skills with my thoughts.
ST-1	Very comfortable	It hasn't changed completely, but I have integrated the methods we used in this process into myself and I plan to work with and again.	i didn't get any feedback
ST-9	Somewhat comfortable	Thanks to these experiences, I understood the importance of three-dimensional thinking, and while making my current design, I work towards three-dimensional thinking and progress my process more efficiently.	As a result of the methods, we applied sequentially, I always made my designs in a more practical way than before. For example, I had a hard time working on the tablet, but thanks to the tablet, I learned the program and made my design more easily in VR.
ST-10	Somewhat comfortable	While I used to think in 2 dimensions, I now give more importance to 3 dimensions because I have seen the perception it creates.	No, it doesn't affect

	Q8	Q9	Q10
ST-1	Maybe creating a group with using VR for 1 week and would have variety answers so trying this would help.	Of course,	Actually, I don’t have any recommendations to say.
ST-9	According to the students’ knowledge which application is will be used can be change.	Yes, of course.	For my studio project I am planning to present with VR because it can show my design in a detailed way. After all, I believe that as usual I am thinking of lots of details in my project and trying to show those in plans, sections diagrams etc. but I believe VR will make a difference and can present my project better. After one week what I thought was this one, for now.
ST-10	What comes to mind is that, for instance, the limitations of the application restrict imagination and design. While we can be more creative on paper, I've noticed that organic designs cannot yet be created in the application as the necessary tools are not available. By adding these, the design environment can be further diversified, providing a more open design space with tools that allow for all kinds of design approaches.	Of course, yes	I see integrating education with this kind of new technology as a very successful and promising approach for the future.
ST-4	Since I do not have much knowledge of the content of the study, I do not have any recommendations.	I would like yes	I have no additional comments
ST-6	In fact, I believe that if this technology is developed more as a tool, it can be more helpful in an architectural project.	Of course, it is very valuable to experience and learn about these innovations.	Although I actually thought the program had shortcomings, the language of the program was easy and fluent. And even though a week has passed, I still remember all the information.
ST-5	The application needs to be improved, it was restricting the design and it was a bit boring since we were designing 9m², it can become more fun in larger projects.	yes, exactly I want	nothing more

ST-2	First of all, the program must definitely be improved. The game idea was one of my favorite ideas. I think it can be used not only for teaching purposes but also for design. For example, a studio topic might be students collectively designing a new town, city, etc. for a game.	definitely	I think a longer trial is needed to see a real after-effect on design process.
ST-8	I realized that I needed to equalize my digital skills with my thoughts.	Of course, it would be really good chance to be part of the new world of technology.	I am happy to be part of this work. It changed my thoughts to the technology. I wish everyone could experiences this study.
ST-1	Perhaps the application on the iPad can also be made suitable for organic designs. By teaching VR technologies, it can be easier to understand the time of inclusion in the design.	yes	It was a useful work for us. It was a nice experience to see that new technologies could destroy the conventional.
ST-9	Our working process was good. Having stages helped us perceive the differences better. Only the game we play can be changed. It could be a game we could design. I think it would be very useful to develop some programs where we can create designs in VR within our workspace.	yes	Programs to increase our architectural skills should definitely be used in the VR environment.
ST-10	This study should definitely be carried out over a longer period of time, so that the effect of these technologies on design students will be clearer.	Of course, I would like to participate with pleasure.	These studies should be carried out in groups rather than individually. Architects or prospective architects who will design should experience designing together in a virtual environment.

4.7. Observation Charts

4.7.1 ST-1

Observations Z NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-1**
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)				■		
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)			■			
- Engaging Environment Challenges (1-5)			■			
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations Y NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-1**
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)				■		
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)			■			
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations X NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-1**
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.2 ST-2

Observations Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-2**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)			■			
- Interaction with environment (1-5)			■			
- Interaction with tools (1-5)			■			
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			■			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)			■			
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)			■			
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-2**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)			■			
- Engaging Environment Challenges (1-5)			■			
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-2**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:	AYSEGUL KIDIK					
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.3 ST-3

Observations Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:						
DATE/TIME	ST-3					
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:	AYSEGUL KIDIK					
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)			■			
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)			■			
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)		■				
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations. Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-3					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:	AYSEGUL KIDIK					
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)		■				
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-3					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:	AYSEGUL KIDIK					
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.4 ST-4

Observations. Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-4**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			■			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)		■				
- Presentation Studies Efficiency (1-5)		■				
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)			■			
RESEARCHER NOTES:						

Observations. Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-4**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)			■			
- Interaction with environment (1-5)			■			
- Interaction with tools (1-5)			■			
- Interaction with peers (1-5)			■			
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			■			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)			■			
- Presentation Studies Efficiency (1-5)			■			
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)		■				
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-4**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)			■			
- Interaction with environment (1-5)			■			
- Interaction with tools (1-5)			■			
- Interaction with peers (1-5)				■		
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)		■				
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)		■				
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)		■				
- Presentation Studies Efficiency (1-5)		■				
CHALLENGES						
- Using Tools Challenges (1-5)			■			
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)			■			
RESEARCHER NOTES:						

4.7.5 ST-5

Observations. Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-5**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			■			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)			■			
- Presentation Studies Efficiency (1-5)			■			
CHALLENGES						
- Using Tools Challenges (1-5)			■			
- Engaging Environment Challenges (1-5)			■			
- Design Challenges (1-5)				■		
- Design Process Challenges (1-5)				■		
- Student Motivation Challenges (1-5)			■			
RESEARCHER NOTES:						

Observations. Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-5**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)			■			
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-5**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.6 ST-6

Observations Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-6					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-6					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-6					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.7 ST-7

Observations — Z NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-7**
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				X		
- Interaction with environment (1-5)				X		
- Interaction with tools (1-5)				X		
- Interaction with peers (1-5)					0	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				X		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				X		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			X			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			X			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				X		
- Presentation Studies Efficiency (1-5)				X		
CHALLENGES						
- Using Tools Challenges (1-5)		X				
- Engaging Environment Challenges (1-5)		X				
- Design Challenges (1-5)		X				
- Design Process Challenges (1-5)		X				
- Student Motivation Challenges (1-5)	X					
RESEARCHER NOTES:						

Observations — Y NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-7**
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				X		
- Interaction with environment (1-5)					X	
- Interaction with tools (1-5)				X		
- Interaction with peers (1-5)					0	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					X	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					X	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				X		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				X		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				X		
- Presentation Studies Efficiency (1-5)				X		
CHALLENGES						
- Using Tools Challenges (1-5)		X				
- Engaging Environment Challenges (1-5)		X				
- Design Challenges (1-5)		X				
- Design Process Challenges (1-5)		X				
- Student Motivation Challenges (1-5)	X					
RESEARCHER NOTES:						

Observations — X NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-7**
DATE/TIME	
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL
RESEARCHER NAME:	

	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					X	
- Interaction with environment (1-5)					X	
- Interaction with tools (1-5)					X	
- Interaction with peers (1-5)					0	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					X	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					X	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					X	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					X	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					X	
- Presentation Studies Efficiency (1-5)					X	
CHALLENGES						
- Using Tools Challenges (1-5)	X					
- Engaging Environment Challenges (1-5)	X					
- Design Challenges (1-5)	X					
- Design Process Challenges (1-5)	X					
- Student Motivation Challenges (1-5)	X					
RESEARCHER NOTES:						

4.7.8 ST-8

Observations. Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-8**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations. Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-8**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	**ST-8**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.9 ST-9

Observations. Z-NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-9**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			■			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)		■				
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations. Y-NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-9**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN

Observation Chart:

STUDENT NAME:	**ST-9**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.7.10 ST-10

Observations. Z-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-10					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)		■				
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations Y-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-10					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)				■		
- Interaction with environment (1-5)				■		
- Interaction with tools (1-5)				■		
- Interaction with peers (1-5)				■		
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)				■		
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)				■		
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)				■		
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)				■		
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)				■		
- Presentation Studies Efficiency (1-5)				■		
CHALLENGES						
- Using Tools Challenges (1-5)		■				
- Engaging Environment Challenges (1-5)		■				
- Design Challenges (1-5)		■				
- Design Process Challenges (1-5)		■				
- Student Motivation Challenges (1-5)			■			
RESEARCHER NOTES:						

Observations. X-NAMED DESIGN						
Observation Chart:						
STUDENT NAME:	ST-10					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)			■			
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)			■			
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)			■			
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)			■			
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)			■			
- Presentation Studies Efficiency (1-5)			■			
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)			■			
- Design Process Challenges (1-5)			■			
- Student Motivation Challenges (1-5)			■			
RESEARCHER NOTES:						

4.7.11 ST-11

Observations						
Observation Chart:						
STUDENT NAME:	**ST-11**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	VR HEADSET					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)		■				
RESEARCHER NOTES:						

Observations						
Observation Chart:						
STUDENT NAME:	**ST-11**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	SCREENS					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

Observations						
Observation Chart:						
STUDENT NAME:	**ST-11**					
DATE/TIME						
DESIGN ENVIRONMENT (Studio/Screens/VR Headset)	CONVENTIONAL					
RESEARCHER NAME:						
	1	2	3	4	5	NOTES
GENERAL OBSERVATIONS						
- Engagement (1-5)					■	
- Interaction with environment (1-5)					■	
- Interaction with tools (1-5)					■	
- Interaction with peers (1-5)					■	
ANALYZE PHASE						
- Analyze Studies Efficiency (1-5)					■	
SYNTHESIS PHASE						
- Synthesis Studies Efficiency (1-5)					■	
CONCEPT PHASE						
- Conceptual Studies Efficiency (1-5)					■	
DESIGN IMPROVEMENT PHASE						
- Design Improvement Studies Efficiency (1-5)					■	
FINAL DESIGN & PRESENTATION PHASE						
- Final Design Studies Efficiency (1-5)					■	
- Presentation Studies Efficiency (1-5)					■	
CHALLENGES						
- Using Tools Challenges (1-5)	■					
- Engaging Environment Challenges (1-5)	■					
- Design Challenges (1-5)	■					
- Design Process Challenges (1-5)	■					
- Student Motivation Challenges (1-5)	■					
RESEARCHER NOTES:						

4.8 Assessment Rubrics

GRADE Weight | Excellent (90-100) | Very Good 80-89 / Good (70-80) | Fair (50-69) | Poor (0-49)

STUDENT: ST-1			
	Design Environment & Tools		
Assessment Rubric	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	15	17	17
Functionality & Practicality (%25)	20	20	20
Spatial Efficiency (%25)	22	18	20
Technical Proficiency (%10)	8	6	7
Representation (%15)	11	10	10
Total	76	71	74

STUDENT: ST-2			
	Design Environment & Tools		
Assessment Rubric	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	19	16	16
Functionality & Practicality (%25)	20	16	17
Spatial Efficiency (%25)	20	16	17
Technical Proficiency (%10)	8	6	7
Representation (%15)	10	10	10
Total	77	64	67

STUDENT: ST-3			
	Design Environment & Tools		
Assessment Rubric	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	22	20	22
Functionality & Practicality (%25)	22	22	22
Spatial Efficiency (%25)	22	22	22
Technical Proficiency (%10)	8	8	8
Representation (%15)	12	12	12
Total	86	84	87

STUDENT: ST-4			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	11	20	15
Functionality & Practicality (%25)	15	20	15
Spatial Efficiency (%25)	18	22	17
Technical Proficiency (%10)	7	8	6
Representation (%15)	8	11	8
Total	59	81	61

STUDENT: ST-5			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	20	15	15
Functionality & Practicality (%25)	22	17	15
Spatial Efficiency (%25)	22	17	17
Technical Proficiency (%10)	8	7	7
Representation (%15)	8	10	9
Total	80	66	63

STUDENT: ST-6			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	21	23	22
Functionality & Practicality (%25)	20	22	22
Spatial Efficiency (%25)	20	22	22
Technical Proficiency (%10)	7	9	9
Representation (%15)	7	13	13
Total	75	89	88

STUDENT: ST-7			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	23	19	19
Functionality & Practicality (%25)	22	22	21
Spatial Efficiency (%25)	21	22	21
Technical Proficiency (%10)	8	9	8
Representation (%15)	12	11	11
Total	86	85	82

STUDENT: ST-8			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	23	23	20
Functionality & Practicality (%25)	22	22	22
Spatial Efficiency (%25)	21	20	20
Technical Proficiency (%10)	8	7	7
Representation (%15)	12	13	13
Total	86	85	82

STUDENT: ST-9			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	23	23	20
Functionality & Practicality (%25)	22	22	22
Spatial Efficiency (%25)	22	21	21
Technical Proficiency (%10)	8	8	8
Representation (%15)	12	13	12
Total	87	89	83

STUDENT: ST-10			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	12	16	16
Functionality & Practicality (%25)	17	16	16
Spatial Efficiency (%25)	17	17	17
Technical Proficiency (%10)	7	7	7
Representation (%15)	7	11	11
Total	60	67	67

STUDENT: ST-11			
Assessment Rubric	Design Environment & Tools		
	Design with Conventional Tools (Conventional Design Studio Environment)	Design with Screens (VR and/or AR Environment)	Design with VR Headset (VR and/or AR Environment)
Design Concept & Creativity (%25)	20	21	20
Functionality & Practicality (%25)	20	21	21
Spatial Efficiency (%25)	22	21	21
Technical Proficiency (%10)	8	8	8
Representation (%15)	11	12	12
Total	81	83	82

CURRICULUM VITAE

2001 – 2006	B.Sc., Architecture, Erciyes University, Kayseri, TURKEY
2006 – 2010	M.Sc., Architectural Design Computing, Istanbul Technical University, Istanbul, TURKEY
2007 – 2016	Architect, Architecture Office, Kayseri, Turkey
2019 –	Lecturer, Architecture, Abdullah Gul University, Kayseri, TURKEY

SELECTED PUBLICATIONS AND PRESENTATIONS

Kidik, A., & Asiliskender, B. (2024). An insight into architectural design studio education space from a "time" perspective. *Journal of Design for Resilience in Architecture and Planning*, *5*(2), 185–201. https://doi.org/10.47818/DRArch.2024.v5i2127.

Kidik, A., & Asiliskender, B. (2024). XR experience in architectural design studio education: A systematic literature review. *Journal of Design Studio*, 6(1), 153-167.

Kidik, A., & Asiliskender, B. (2024, accepted by August 2024). Exploring mixed reality in architectural design education: A systematic review. *DEPARCH Journal of Design Planning and Aesthetics Research*.

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Kevseroğlu, Ö., Kıdık, A., & Asiliskender, B. (2020, May 6-8). Continuity of industrial landscape: From Sümerbank Kayseri Textile Factory to AGU Sumer Campus. In International *Conference of Contemporary Affairs in Architecture and Urbanism (ICCAUA-2020)*, Alanya, Antalya, Turkey, 6-8 May 2020.