



Integrating Immersive Technologies to Architectural Design Studios

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Abstract

This research investigates the transformative potential of immersive technologies—Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—in architectural education, with a particular focus on their application within design studios. It addresses the evolution of architectural pedagogy from its classical origins, characterized by the master-apprentice model, through the formalized education systems of the traditional period, to the contemporary era where digital and immersive technologies play a pivotal role.

The study is anchored in a mixed-method research design, integrating both quantitative and qualitative approaches to provide a comprehensive evaluation of the impact of VR, AR, and MR on architectural education. Quantitative data were collected through pre- and post-experiment questionnaires administered to a diverse cohort of students and educators. Qualitative insights were garnered from in-depth interviews and case studies conducted across multiple educational institutions. These methods collectively facilitated a robust analysis of how immersive technologies influence teaching methodologies, student engagement, and educational outcomes.

The thesis begins with a literature review that traces the historical context of architectural pedagogy, highlighting key developments and shifts that have shaped the design studio as the core of architectural education. The classical period, marked by the apprenticeship system and the Ecole des Beaux-Arts model, laid the groundwork for the studio-based learning approach. The traditional period saw the formalization of architectural education within academic institutions, influenced significantly by Donald Schon's theories on reflective practice and experiential learning.

The core of the research focuses on contemporary architectural education and the integration of immersive technologies. The study identifies several key benefits of VR, AR, and MR in design studios, including enhanced spatial understanding, improved creativity, and more effective communication between students and educators. Immersive environments allow students to visualize and interact with architectural designs in a more tangible and realistic manner, fostering innovative problem-solving and design thinking. The research also explores the pedagogical implications of these

technologies, demonstrating how they can support a more interactive and student-centered learning experience.

However, the adoption of immersive technologies in architectural education is not without challenges. The thesis addresses critical issues such as the high cost of equipment, the need for specialized training for both students and educators, and the complexities of integrating these technologies into existing curricula. Despite these challenges, the findings indicate that the benefits of VR, AR, and MR far outweigh the drawbacks, providing a compelling case for their inclusion in architectural education.

The research is guided by Bloom's Taxonomy, ensuring that the educational objectives align with higher-order thinking and deeper cognitive engagement. By employing Bloom's framework, the study emphasizes the importance of fostering creativity, communication, and confidence in students through the use of immersive technologies. The findings suggest that VR, AR, and MR can significantly enhance the quality of architectural education, preparing students for the demands of the modern architectural profession.

The thesis concludes with practical recommendations for educators and institutions aiming to integrate immersive technologies into their curricula. These recommendations are based on the research findings and best practices identified through the case studies and interviews. The study advocates for a strategic approach to technology integration, emphasizing the need for adequate resources, training, and support to maximize the educational benefits of VR, AR, and MR.

Overall, this research contributes to the growing body of knowledge on the use of immersive technologies in education. It provides valuable insights into the potential of these tools to revolutionize architectural pedagogy, offering a roadmap for educators and institutions seeking to enhance their teaching practices and improve student learning outcomes. The research underscores the transformative potential of VR, AR, and MR, positioning them as critical components of the future of architectural education.

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Chapter 1: General Introduction

1.0 Introduction

This chapter establishes the foundational context and justification for the research, focusing on the integration of immersive technologies—namely Virtual Reality (VR) and Augmented Reality (AR)—within architectural education. It begins by tracing the historical evolution of the architectural design studio as the central pedagogical model, highlighting how traditional educational practices have progressively incorporated digital tools to enhance design learning. The chapter then explores the transformative potential of immersive technologies, emphasising their ability to facilitate more interactive, spatially immersive, and collaborative learning experiences in design studios. By situating these discussions within the broader context of architectural education, this chapter articulates the need for this research and outlines the specific research aims, questions, and objectives. The chapter concludes by presenting the methodological approach employed in the study and offers a brief overview of the chapters that follow.

Contemporary and traditional forms of architectural pedagogy originate from the design studio where the design studio can be considered the heart and soul of architectural education in any faculty across the globe. To understand and research on architectural pedagogy one must explore and understand what element or aspect defines and dictates the field of study. In the case of architectural pedagogy, it is imperative to study the essence of design studios and the literature that is written on design studios. One of the most influential and crucial literature on architectural pedagogy is Donald Schon's 'The Reflective Practitioner' for its specificity and emphasis on design studios (Schön, A, D., 1984). The emergence of the academic design studio is more dominantly evident in the early 20th Century when architectural education integrated into institutional structures (Toward a Marriage of Artistry & Applied Science in the Architectural

Design Studio, (no date)). However, research suggests that it has been present in classical pedagogy for approximately 260 years, though the methods and performance of classical design studios were carried out very differently from both contemporary and traditional design studios (Ockman, 2012).

For clarification, this study identifies and refers to three time periods in architectural education. These are focused on events happening after the emergence of studio models and the decline of ancient master and apprentice models. Firstly, the classical period in architectural education began approximately 260 years ago till the early 20th century (Cunningham, A., 2005). Secondly, the traditional refers to the period between the early 20th century and the beginning of the 21st Century (Frazer, 2000), at which point computers were introduced, marking the beginning of contemporary education and the third period (Banathy, H, B., 2001). Multiple factors have dictated the need for change in each of these three periods. These multiple factors, or points of departure, are always caused by pressures mainly from the practice sector and demands in the education sector. The two sectors work simultaneously as one's pressure creates the demand in the other. Technological innovation, particularly in immersive technologies such as VR and AR, is increasingly viewed as beneficial to both architectural practice and education. In practice, these tools allow architects to visualize and iterate designs more efficiently, offering real-time insights into spatial dynamics and construction details (Tan, S., Yang, Y. and Milano, d, P, I., 2019). In education, immersive technologies foster more interactive and engaging learning experiences, enabling students to better understand complex architectural concepts through direct, hands-on interaction in virtual environments (Alizadehsalehi, S., Hadavi, A. and Huang, C, J., 2019). The convergence of these innovations across both sectors is driving a transformation in how architecture is both taught and practiced, with immersive technologies playing a central role in blurring the boundaries between education and professional practice. This increasing fluidity facilitates a more integrated learning approach, where students engage with digital tools and workflows that mirror industry standards, reinforcing the argument that immersive technologies

enhance architectural pedagogy by bridging academic and professional competencies (Schumacher, 2022).

Architectural education has continually evolved in response to a range of pressures, notably from the professional and academic sectors. These include the demands of the practice sector for greater efficiency, precision, and technological fluency in design, and the parallel expectations from the educational sector to enhance student engagement and improve pedagogical outcomes (Soliman, Taha, & Sayad, 2019). These pressures, already evident in the shift from traditional to contemporary approaches, serve as key points of departure for rethinking architectural curricula in light of immersive technological innovations. The evolution of architectural pedagogy and the increasing integration of immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) have been significantly shaped by advancements in information technology. To fully understand the impact of these technologies on education and practice, it is important to explore key concepts from the field of IT that underpin immersive experiences in architecture. Two terms are applied to the world of information technology: cyberspace and virtual reality. The term "cyberspace" was first used by William Gibson (1984) in the book entitled "Neuromancer" (Gibson, W., 1995) to illustrate the imaginary world experienced by engaging within a globally networked data space. Therefore, cyberspace indicates the data space of the computer. All data are entered by the system users (Cyberspace, 2009). Virtual reality means the world users experience while using the data system (Bryant, R., 2001). It involves more emotional situations than what cyberspace can offer. In this paper, the definition of virtual reality refers to the data space in which some subset of human senses can be stimulated and reflected (Latta, N, J. and Oberg, D., 1994).

Virtual reality (VR) environments provide an immersive experience in which participants wear tracked glasses to view stereoscopic images, listen to 3-D sounds, and are free to explore and interact within a 3-D world. As an advanced human-computer interaction and interface tool

(Durlach and Mavor, 1995; Mine, 1995a; 1995b), it does not only provide diversified media for visually, aurally, and interactively experiencing architectural design (Ellis, 1991a; 1991b), but also allows designers to perceive, grasp, and move three-dimensional building elements in the VR space. Furthermore, more contemporary VR systems now allow for designing, creating, modifying 3D elements on the spot with multiple users. Such systems and immersive environments can even allow multiple users to interact and collaborate together either physically in the same room or across the globe as can be seen in design software. Contemporary VR systems could potentially change or enhance the nature and/or the manner in which design ideas are discussed and developed in the design studio.

Back in 2019, when this research began the possibilities with designing in VR were far more limited than it is today. In a VR space/ environment, virtual displays surround users with three-dimensional stimuli. Users feel like inhabiting a new place instead of looking at a picture. With sensory immersion in the VR space, users become a part of the environment and can perceive the surroundings by walking around the space. For architectural designers, applying VR has the potential to enable them to understand the spatial qualities of their designs immediately, and will be able to comprehend their works by walking through the virtual space to visualize the colour and texture of assigned materials, proportions of the spatial layout, and the aesthetic expression of structural elements. Therefore, VR has the potential to become a valuable visual tool for architectural learning/teaching and is now in the rapidly developing research stage. As the years progressed we now have software such as Arkio and Gravity Sketch where we begin to take the possibilities to the next level. Perhaps it could even be stated that this new design software marks a new chapter in how we use immersive technologies in design dialogue and thinking. Advanced architectural software now enables users to engage in highly interactive, immersive design processes, allowing for real-time creation, modification, and spatial exploration of both objects and environments. The integration of such systems introduces new potentials, including enhanced iterative design workflows, real-time collaboration, and spatial cognition

development, which were previously constrained by traditional 2D and static 3D modeling tools (Whyte, 2002; Oxman, 2008; Birt et al., 2018). Given these advancements, it becomes essential to investigate how these emerging capabilities influence architectural design thinking and pedagogical approaches. Understanding this relationship is key to determining whether immersive technologies merely supplement existing methodologies or fundamentally transform the way architectural education is structured.

1.1 Motivation for the Research

The motivation for this research stems from the recognition of the increasing importance and potential impact of immersive technologies in architectural education. The use of immersive technologies such as virtual reality, augmented reality, and mixed reality has the potential to greatly enhance the learning experience for architecture students (Ummihusna & Zairul, 2021). These technologies can provide immersive and interactive environments that allow students to visualize and experience architectural designs in a more realistic and engaging way. Furthermore, the integration of immersive technologies can encourage active learning, collaborative problem-solving, and critical thinking skills among students. This research aims to explore the effectiveness and potential impact of integrating immersive technologies in architectural education. The data and results obtained from this study give insight into the planning of design studios in architecture education based on the use of VR and digital methods.

1.1.1 Statement of Research Problem

To date VR and AR is extensively used as a walkthrough experience, only visualising buildings in architectural design discussions. However, tools are now available that allow for a more interactive experience that can be used in the design process. In the academic field, the use of VR and AR should not be limited to providing an elaborate walkthrough experience toward the end of a project but should instead serve as an exploratory tool during the design stage (Tan et

al., 2019). While concept models and physical modeling have traditionally been used in early-stage design development to test spatial relationships and materiality, VR and AR offer a more dynamic and iterative approach, enabling real-time manipulation of design elements, immersive spatial perception, and collaborative digital environments. Unlike physical models, which provide a tangible but static representation, immersive modeling allows students to inhabit, modify, and experience their designs at full scale, providing a level of interaction and feedback that is not possible with traditional methods. This distinction highlights the need for integrating immersive technologies earlier in the design process, not as a replacement for physical modeling, but as an enhancement that complements traditional exploratory techniques. Unlike in other fields, the presence and production of a VR/AR model should be integrated from the early stages of the design process due to its potential to significantly enhance creativity, improve communication among stakeholders, and boost designers' confidence in their decisions. While traditional physical models allow for quick, intuitive exploration with minimal overhead, VR/AR modeling introduces a different but complementary design workflow. Although digital model creation may require an initial investment of time and technical proficiency, it compensates by enabling rapid iteration, immersive spatial testing, and real-time feedback loops, which are not possible with physical models alone. Additionally, VR/AR fosters collaborative decision-making, allowing multiple participants to inhabit and evaluate design options simultaneously. Rather than replacing the spontaneity of traditional sketch models, VR/AR should be viewed as an augmentative tool that enhances design exploration by providing a level of spatial engagement and iterative refinement that physical models cannot achieve. Moreover, in architectural practice, the VR/AR models are rarely made to be interactive or have real-time editing features, as most of the time, the sole purpose is to provide the clients, engineers and builders with an accurate representation of the proposed design space (Liu, Y. et al., 2020). A highly trained design professional will have a far greater and easier spatial cognition of a proposed scheme from 2D plans, elevations and 3D walkthroughs on a 2D screen (Sun, L. et al., 2014). For the

untrained user, the intended use of VR and AR will be capped at just perceiving a sense of space and scale (Paes, D., Arantes, M, E. and Irizarry, J., 2017). Numerous amounts of research regarding the use of VR and AR in architectural pedagogy have been undertaken with the hopes of improving communication between tutors and students during critique sessions (Alizadehsalehi, S., Hadavi, A., & Huang, C. J., 2019; Aydın, S., & Aktaş, B., 2020; Lang, S., & Hovestadt, L., 2003).

The most fruitful moments for a student in any critique session are observing and participating in the design moment with their tutor (Goldschmidt, G., Hochman, H. and Dafni, I., 2010). A healthy collaborative design experience has the potential to drive the students' design evolution to greater heights. One of the main issues with the above-said design moment is the lack of collaboration and communication during the design moment. The quality of the above-said design moment is measured with collaboration and communication during the design moment. Integrating pedagogical strategies can enhance these collaborative moments, fostering critical thinking and deeper understanding among students (Tucker, 2017). Traditionally, architectural pedagogy required skill, training and knowledge using pen and paper and physical models. The more skill a student had the more fruitful the design moments were for them. In the current era, the education system prior to university is different when compared to traditional times. There is less emphasis on the depth of skill and knowledge an average student receives (Ou and Cheng, 2016). Most often faculties try to compensate this issue by demanding first year students to rely on traditional methods along with supporting workshops. The idea behind this approach also stems from an additional factor, that being popularity and reliance of CAD in design studio. A lack of traditional preparation combined with reliance and speed of CAD limits student creativity, cognition and expression. Students do not marinate on design ideas and put less thought to the process only aiming for results (Veisz et al., 2012). Traditional methods, while comparatively

slow, allow students to think more on the concept and meaning of their design. Contemporary CAD provides speed in getting visuals and testing out visuals, however students become focused on getting nice aesthetic visuals. Students lose sight of design values which is obtained when thinking during the design process (Lawson, 2002). Immersive Technologies have the potential to draw strengths of both methods and further enhance the design moment. VR and AR systems combined with a user-friendly interface can be implemented to provide real-time detailed design experience of designing and discussing an accurate representation of a project with multiple users in real-time editing could easily become the pinnacle of architectural pedagogy (Milovanovic et al., 2017).

1.1.2 State of Immersive Technologies prior to 2020

The efficiency of the software and the interface used dictate the success of the mixed VR/AR system. Prior to 2020, the main problem in feasibility of integrating mixed VR/AR (or MR) to education system would be to provide the multi-user room experience without the use of two separate sets of gear connected through a network (Nor'a and Wanis, 2019). Certain organisations (Draw and Code) and universities (LJMU) in Liverpool collaborated to provide the above-mentioned multi-user experience enhanced with the use of physical models of buildings (LJMU AR Experience, 2020). Their project aimed to use crude physical models of buildings and map the VR façade variations that will be tracked and follow the real-time disposition of the physical model while more than one person is able to see the edit and design changes through the use of headgear. The development and refinement of multi-users provided the missing piece to the puzzle. Since communication and collaboration are key measures of a design studio, the multi-user feature plays a crucial role in integrating immersive technologies by promoting participatory design (Hajirasouli and Banihashemi, 2022).

As previously mentioned, designing moments during any given critique session is aimed at helping students learn how to design, either by seeing their tutor designing or by experiencing a

collaborative design with their tutor (Hultén, M., Artman, H. and House, D., 2016). During design studio critique, students and tutors discuss design issues that will drive the evolution of the students' designs. Designing can be performed during the session by the student, the tutor, or both. This moment is pedagogically important, and collaboration and communication should be a primary concern because it will determine the success of the project (Beier, S., 2014). Conversations on design issues and potential solutions revolve around design representations. Miscommunication between students and tutors can penalize and disrupt the learning potential of the discussion. The lack of constructive communication is driven by misunderstandings that can be a consequence of the gap between the design expertise of both student and tutor. The lack of communication will also result in differing creative visions of design values between the tutor and student (Saridar Masri, S., 2017).

1.1.3 Substantial Software and Hardware Selection Procedure

The implementation and application of virtual reality (VR) systems present several challenges, primarily concerning equipment cost, the need for user expertise and training, and the complexity of software and user interface development (Wang, 2008). One of the key factors affecting cost is the growing popularity of VR within the gaming industry, which has led to more immersive and affordable equipment becoming accessible on the open market. However, VR technology still requires high-performance desktops with advanced graphical capabilities to function effectively (Peinl and Wirth, 2020).

This challenge is somewhat alleviated by Moore's Law, which suggests that computing power doubles approximately every two years, while the relative cost of that power remains steady or even decreases (Chien and Karamcheti, 2013). As a result, the continuous development of more powerful and efficient hardware has made it possible for companies to offer high-performance desktops and graphics cards at increasingly affordable prices. For example, a desktop with top-tier specifications two years ago will have depreciated significantly as newer and more powerful

graphics cards are introduced (Trends in GPU Price-Performance, 2022; Worldwide PC Forecast, 2023).

Additionally, industries beyond gaming, such as cryptocurrency mining, have also driven the demand for high-performance graphics cards, further influencing the market. Consequently, due to the competitive nature of these industries and the accelerating pace of technological advancement, VR equipment and the required computing hardware are becoming progressively more affordable (Whyte & Nikolić, 2018).

Another significant challenge lies in the level of user expertise and training required for effective VR system operation. While VR technology has become more user-friendly in recent years, it still demands a certain level of technical proficiency. Users must be trained not only in operating the hardware but also in navigating complex software environments (Dodoo et al., 2018). This need for training can be a significant barrier to adoption, especially in industries where users may not have a technical background. Without proper training, the immersive potential of VR systems may not be fully realized, leading to inefficient use of resources or suboptimal user experiences (Kaplan et al., 2019).

In addition to the hardware and user expertise, the complexity of software and user interface development presents a formidable challenge. VR applications require specialized software that can seamlessly integrate 3D models, graphics, and sensory feedback to create an immersive experience. Developing these interfaces is complex, as they must be intuitive yet capable of handling sophisticated interactions in real-time (Diefenbach, 2002). Furthermore, VR software must be optimized for high-performance hardware to ensure smooth operation, which requires extensive programming and design efforts. Balancing functionality, usability, and performance remains a critical hurdle in the development of effective VR systems (Gutiérrez, Vexo and Thalmann, 2006).

1.2 Expected Contribution to Knowledge

This PhD research aims to contribute to the evolving discourse on the integration of immersive technologies—namely Virtual Reality (VR) and Augmented Reality (AR)—in architectural education, specifically within the design studio setting. Through a combination of experimental research and pedagogical reflection, this work addresses the gap between traditional architectural pedagogy and the potential for immersive technologies to enhance creative design thinking, student engagement, and reflective learning.

Central to this contribution is the emphasis on experimentation and discovery, which are fundamental to the design process in both traditional and immersive environments. These concepts will be explored in the context of architectural pedagogy, where learning through doing, iterative experimentation, and reflective practice are integral components of the educational process. As Schön (1991) described in his theory of 'reflection-in-action,' the design studio is not just a space for producing creative work but also a reflective arena where students develop problem-solving skills through continuous feedback and iterative refinement. This PhD expands on Schön's theory by exploring how VR/AR can enhance this reflective process, enabling students to interact with their designs in real-time and fostering deeper cognitive engagement.

A key element of this research is the examination of VR/AR as platforms that afford a more immersive and interactive design experience. Unlike traditional CAD tools, which are often seen as limiting students' flexibility due to the speed and finality of digital drawings, immersive technologies encourage iterative design and open-ended exploration. In this regard, the human-centered approach to VR/AR enhances creative thinking, providing students with new tools to engage more naturally with their ideas and reflect on their decisions as they evolve throughout the design process. This focus on creative exploration ties back to the 'play-and-learn' mentality, where VR/AR becomes a sandbox for architectural experimentation, allowing students to visualize and manipulate spatial forms in unprecedented ways.

Furthermore, this research will explore how VR/AR can harmonize the empirical and humanistic aspects of architectural education. Current architectural pedagogy often emphasizes empirical metrics, such as design efficiency and performance-based outcomes (Subagio & Qudus, 2019), while immersive technologies offer a unique opportunity to blend these with the more qualitative aspects of creative thinking and reflection. This research will contribute to knowledge by demonstrating how VR/AR can bridge the gap between these two aspects, fostering a learning environment that is both empirically grounded and creatively enriching.

In summary, this PhD expects to contribute to the understanding of how immersive technologies can transform architectural education. By situating these tools within the broader context of architectural pedagogy, this research will offer insights into the pedagogical benefits of VR/AR, particularly in enhancing creativity, communication, and reflective learning. This work not only promotes the importance of adopting new technologies but also provides a framework for their effective integration into architectural curricula.

Integrating immersive technologies into architectural education offers significant benefits, yet several challenges hinder widespread adoption. Concerns about high implementation costs, steep learning curves, and resistance due to traditional pedagogical biases are prominent. Addressing these issues is crucial for a smoother transition and to maximize the educational advantages of these technologies.

1.2.1 Challenges in the Adoption of Immersive Technologies in Architectural Education

Despite the growing interest in immersive technologies within architectural education, their adoption remains hindered by several key challenges. The most frequently cited barriers include high implementation costs, steep learning curves, and resistance due to traditional pedagogical biases (Alizadehsalehi et al., 2020; Vergara et al., 2023). Addressing these obstacles is essential to ensuring a seamless integration of these technologies and maximizing their pedagogical potential.

One of the most significant challenges in the widespread implementation of immersive technologies is the high cost of hardware and software infrastructure. Many institutions face financial limitations that prevent them from acquiring the necessary equipment, such as Head-Mounted Displays (HMDs), Computer-Assisted Virtual Environment (CAVE) systems, and high-performance computing resources. Additionally, ongoing expenses related to software licensing, updates, and maintenance further exacerbate these financial concerns. Studies have identified cost as a primary barrier, particularly in developing countries and resource-constrained institutions (Wang & Schnabel, 2019; Alizadehsalehi et al., 2020).

Both students and educators experience steep learning curves when transitioning to immersive technologies. Many educators, particularly those trained in traditional architectural pedagogy, require extensive training and adaptation periods to integrate VR and AR into their teaching methodologies effectively (Vergara et al., 2023). Furthermore, research suggests that while immersive tools enhance learning experiences, their effectiveness is strongly linked to the pedagogical framework in which they are applied. A systematic review of immersive learning technology interventions in architectural education found that a significant gap exists in linking these technologies to established learning theories, leading to inconsistencies in instructional design (Alizadehsalehi et al., 2020).

Institutional resistance to change remains a significant non-technical barrier to immersive technology adoption. Architectural education has historically relied on studio-based, hands-on learning environments, and some educators express scepticism regarding the practical applicability and cognitive benefits of VR and AR in comparison to physical modeling and traditional CAD workflows (Wang & Schnabel, 2019). Additionally, Vergara et al. (2023) highlight that the successful integration of immersive tools in design studios requires institutional support, funding for faculty training, and adjustments to curriculum structures, all of which present logistical challenges.

Overcoming these challenges necessitates strategic planning and phased implementation. Institutions must focus on securing sustainable funding models, providing structured training programs for faculty, and fostering a pedagogical shift towards hybrid learning environments where immersive tools complement, rather than replace, traditional methods. By addressing these barriers systematically, immersive technologies can be effectively integrated into architectural education, ultimately enhancing spatial cognition, creativity, and collaborative learning (Alizadehsalehi et al., 2020; Vergara et al., 2023).

1.3 Research Aim and Objectives

Research Aim – To explore the potential of immersive technologies in delivering high-quality architectural design education, where "quality" is defined as an educational experience that enhances creativity, spatial cognition, design iteration efficiency, collaboration, and student engagement.

Research Objectives

- 1) To determine and understand the global role of design studios in the standard architectural pedagogic model in Architecture.
- 2) To determine and understand the existing process of assessing immersive technologies for their potential integration and attributes used in education.
- 3) To determine the awareness of educators and students in the concept of enhancing education via immersive technologies and how this understanding is reflected in design studios.
- 4) To critically evaluate the challenges educators and faculties face in delivering immersive technology-integrated architectural education.
- 5) To develop a conceptual framework, if none existed, to guide/inform educators and faculties in the integration of immersive technologies into their architectural curriculum.

1.4 Key Research Question

The Research questions posed are as follows:

- To what extent do Architectural students and educators understand and subscribe to the concept of designing with CAAD and immersive technologies?
- How does the new design frontier/medium facilitated by immersive technology affect student's creativity?
- How does the virtual learning environment communicate design values in immersive collaborative design sessions?
- Do immersive technologies help students develop inherent design confidence, enhancing their ability to make informed design decisions, engage in reflective practice, and communicate their ideas effectively?

1.5 Research Strategies

The research strategies for this PhD research encompasses the application of immersive technologies—namely Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—within the context of architectural education, with a particular focus on design studios. This study examines both students and educators in architectural programs to evaluate the effectiveness and impact of these technologies on the educational process.

This study's theoretical framework is grounded in Bloom's Taxonomy (Attia, S, A., 2021), a well-established model for classifying educational objectives and cognitive skills. Bloom's Taxonomy is employed to develop learning objectives that promote higher-order thinking and deeper understanding, aligning these objectives with key aspects of creativity, communication, and confidence in architectural education.

Bloom's Taxonomy is a framework that classifies educational objectives and cognitive skills into different levels. This classification helps in developing learning objectives that promote higher-order thinking and deeper understanding by tying it to creativity, communication, and confidence. By using Bloom's Taxonomy as a model for architectural education, educators can ensure that their learning objectives go beyond surface-level understanding and instead focus

on higher levels of cognition such as analysis, synthesis, and evaluation with the aim of enhancing students' creative thinking abilities (Jones & Brown, 2020; Lee & Smith, 2019). In the context of architectural education, the use of Bloom's Taxonomy can be instrumental in designing learning objectives for utilizing immersive technologies to enhance collaboration among students through improved communication skills.

Specifically, this research aims to:

Assess Awareness and Understanding: Determine the level of awareness and understanding among architectural students and educators regarding Computer-Aided Architectural Design (CAAD) and immersive technologies. This includes evaluating their familiarity with these technologies and their perceptions of their educational value.

The first research question in this PhD study explores how awareness and understanding among architectural students regarding Computer-Aided Architectural Design are linked to confidence building when incorporating immersive technologies into design processes. This research question aims to assess the level of familiarity while also gauging its impact on overall student confidence within virtual collaborative design sessions through immersion.

Evaluate Impact on Creativity: Investigate how the integration of immersive technologies influences student creativity. This involves examining the role of immersive environments in fostering innovative problem-solving and design thinking, essential components of architectural education.

The second research question focuses on connecting immersive technologies with student creativity aided by Bloom's taxonomy which supports deep thinking necessary for innovative problem-solving abilities within architecture education settings.

Analyze Communication Efficacy: Explore the effectiveness of virtual learning environments in enhancing communication during collaborative design sessions. This aspect of the study focuses on how VR, AR, and MR facilitate clearer and more effective communication of design ideas between students and tutors.

The third research question revolves around correlating the effectiveness of virtual reality platforms used during collaborative design sessions in fostering effective communication skills essential in conveying architectural concepts clearly across members involved in the design process.

Measure Confidence Building: Examine how immersive technologies contribute to building confidence in students' design and reflective abilities. This includes assessing the impact of these technologies on students' ability to critically engage with their design processes and outcomes.

The fourth research question examines how well blending cognitive dimensions from Bloom's Taxonomy Framework aids effectiveness produced by relying heavily upon technical skill acquisition shifting towards more profound critical thought ability development. Reducing the reliance on rote learning and emphasizing deep understanding and critical thinking is crucial in preparing architectural students for the challenges of the profession.

By utilizing Bloom's Taxonomy as a guiding framework, this study ensures that the educational objectives go beyond surface-level understanding and aim for deeper cognitive engagement. The integration of immersive technologies is evaluated for its potential to transform traditional pedagogical approaches in architectural education, fostering a more interactive, engaging, and effective learning environment.

This research aims to explore how immersive technologies influence architectural education across four key dimensions: awareness and understanding, creativity, communication, and

confidence-building. These dimensions are interconnected and contribute to the broader pedagogical impact of immersive technologies. Awareness and familiarity with Computer-Aided Architectural Design (CAAD) and immersive tools serve as the foundation, influencing students' confidence in integrating these technologies into design workflows. This confidence, in turn, enhances creativity, allowing students to engage in deeper iterative problem-solving within immersive environments. Additionally, the effectiveness of virtual learning spaces in facilitating clearer design communication further strengthens collaborative design sessions, creating a cycle where confidence, creativity, and communication reinforce one another. By structuring the study around these interconnected objectives, this research examines the transformative potential of immersive technologies in enhancing architectural pedagogy beyond traditional methodologies.

1.6 Research Methodology in Brief

This study is guided by both an ontological and epistemological approach, which shape its research methodology and strategy.

Ontology concerns the nature of reality and existence—in this case, it addresses what is present and tested in the field of immersive technologies, forming the structural basis for this research. An ontological approach allows for the identification and classification of existing applications, technological frameworks, and theoretical constructs, enabling the research to evaluate the feasibility of integrating immersive technologies into architectural education. Additionally, it provides technical insights from past literature, ensuring that this study is grounded in established knowledge while allowing for new explorations.

Epistemology, on the other hand, is concerned with the theory of knowledge—how knowledge is gathered, validated, and applied. This study adopts an epistemological analysis to examine the philosophical foundations of architectural pedagogy, its historical evolution, and its cultural

significance. Unlike previous research that may have focused solely on technological application, this study takes a broader theoretical perspective by critically analyzing the humanistic and pedagogical identity of architectural education. This epistemological foundation ensures that the study does not merely assess immersive technologies as tools but evaluates their impact on knowledge creation, learning methodologies, and cognitive development.

By integrating both ontological and epistemological perspectives, this research establishes a structured methodological framework before beginning the data collection stage. The dual approach ensures a well-balanced study that is both technically grounded and philosophically informed, providing a comprehensive understanding of immersive technologies in architectural education.

The research adopts a mixed-method approach for its methodology. The research uses a survey approach to establish demographics before starting its series of case studies. As mentioned, the research adopts Bloom's revised taxonomy and focuses on measuring learning quality and evaluating experience. Architecture is a creative and cognitive endeavour by nature. Therefore, the heavier focus is on the qualitative aspect of the study.

Method Summary:

Case Study Experiments: Three separate case study experiments were conducted, each involving a diverse group of students and tutors. These experiments were designed to provide practical insights into the use of VR, AR, and MR in design studios and to evaluate their impact on the learning process.

Questionnaires:

Pre-Experiment Questionnaires: Prior to the experiments, quantitative questionnaires were administered to gather demographic information and assess participants' knowledge, exposure,

and familiarity with immersive technologies. These questionnaires helped establish a baseline understanding of the participants' backgrounds and initial attitudes towards VR, AR, and MR.

Post-Experiment Questionnaires: After the experiments, qualitative questionnaires were distributed to measure the experiences of both students and tutors. These questionnaires utilized a Likert scale to evaluate key factors such as communication, confidence, and creativity. The aim was to capture detailed feedback on how immersive technologies influenced the design process, interactions, and overall educational outcomes.

The combination of case studies and detailed questionnaires allows for a comprehensive analysis of the effectiveness of immersive technologies in architectural education. The case studies provide contextual and practical insights, while the questionnaires offer measurable data on participant experiences and perceptions. This mixed-methods approach ensures a well-rounded evaluation, addressing both the practical implementation and the theoretical implications of using immersive technologies in design studios.

1.7 Scope of the Research

This research focuses on exploring the application and potential of immersive technologies—specifically Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—in the context of architectural education. The study delves into the ways these technologies can transform traditional design studios into dynamic, interactive learning environments that enhance spatial understanding and design skills.

The research is segmented into several key areas:

Integration of Immersive Technologies in Design Studios: This includes examining the current use of VR, AR, and MR in architectural education and identifying gaps where these technologies can offer significant improvements.

Pedagogical Impacts: Investigating how immersive technologies influence teaching methods, student engagement, and overall educational outcomes. This involves understanding the changes in learning dynamics when students can interact with and manipulate 3D models in real time.

Technical and Practical Challenges: This part of the research addresses the technical hurdles of integrating these technologies, such as hardware and software requirements, user training, and cost implications. It also evaluates the feasibility of widespread adoption in educational institutions.

Case Studies and Practical Applications: Conduct detailed case studies to illustrate the practical application of VR, AR, and MR in architectural education. These case studies provide real-world examples of how immersive technologies are currently being used, their benefits, and the challenges educators and students face.

Future Prospects and Recommendations: Offering a forward-looking perspective on the potential advancements in immersive technologies and proposing recommendations for educators and institutions on best practices for integrating these tools into their curricula.

The scope of this research aims to provide a comprehensive understanding of the role immersive technologies can play in enhancing architectural education, bridging the gap between theoretical knowledge and practical application, and ultimately preparing students for the evolving demands of the architectural profession.

1.8 Significance of the Study

This study's significance lies in its potential to enhance and transform architectural education through the integration of immersive technologies. Prior research suggests that immersive tools, such as Virtual Reality (VR) and Augmented Reality (AR), offer greater engagement, spatial awareness, and iterative design capabilities, which can enrich traditional pedagogical

approaches (Wang & Schnabel, 2019; Vergara et al., 2023). Building upon these established findings, this study investigates how immersive technologies can be effectively implemented to support creativity, communication, and confidence-building in architectural students.

The findings of this research will provide insights that could influence educators, students, and the architectural profession as a whole. By critically assessing the educational value and practical applicability of immersive technologies, this study aims to bridge the gap between theory and practice, offering empirically grounded recommendations for integrating these tools into architectural curricula. The outcomes of this research will contribute to both academic discourse and pedagogical innovation, ensuring that immersive technologies are not just adopted but meaningfully incorporated into architectural education.

Key significance points include:

Enhanced Learning Experiences: By utilising VR, AR, and MR, students can experience architectural designs in a more tangible and immersive way. This hands-on approach allows for better spatial understanding and design iteration, leading to more refined and innovative architectural solutions.

Improved Communication and Collaboration: Immersive technologies facilitate better communication between students and educators, particularly during design critiques and collaborative projects. Real-time editing and interactive environments help bridge the gap between theoretical concepts and practical execution, enhancing the learning experience.

Innovation in Pedagogy: This study contributes to the evolving pedagogical approaches in architectural education. By incorporating immersive technologies, educators can adopt more interactive and student-centred teaching methods, promoting active learning and critical thinking.

Accessibility and Inclusivity: Immersive technologies have the potential to make architectural education more accessible to a wider range of students. VR and AR can provide remote learning opportunities, allowing students from diverse geographical and socio-economic backgrounds to access high-quality architectural education.

Professional Preparedness: As the architectural profession increasingly adopts digital tools and technologies, this study ensures that students are well-prepared to meet industry demands. Familiarity with VR, AR, and MR during their education will give graduates a competitive edge in the job market.

Contribution to Research and Development: The study adds to the existing body of knowledge on the use of immersive technologies in education. It provides valuable insights and data that can inform future research, technology development, and educational policies.

Sustainability and Efficiency: Immersive technologies can contribute to more sustainable architectural practices by enabling more efficient design processes and reducing the need for physical models and materials. This aligns with broader goals of environmental sustainability and resource conservation.

In summary, this study is significant because it explores and validates the transformative potential of immersive technologies in architectural education. It not only enhances the learning experience but also prepares students to be innovative, adaptable, and proficient in the use of cutting-edge technologies in their future careers.

1.9 Structure of the Thesis

The research structure is presented. The contents of each chapter are summarised as follows;

1.9.1 Chapter 1: General Introduction

This chapter provides an overview of the study, including the research problem, aim, objectives, methodology, and significance. It sets the stage for understanding the integration of immersive technologies in architectural education.

1.9.2 Chapter 2: Literature Review

Chapter 2 presents the historical context of architectural pedagogy and the evolution of design studios. It also explores contemporary practices and the integration of digital tools in education, highlighting the need for immersive technologies.

1.9.3 Chapter 3: Context of Research

This chapter reviews existing literature on architectural education, the role of design studios, and the use of immersive technologies. It examines the benefits and challenges associated with VR, AR, and MR in educational settings, providing a theoretical foundation for the study.

1.9.4 Chapter 4: Research Methodology

This chapter details the research methodology, including the ontological and epistemological frameworks. It describes the mixed-method approach used to collect and analyze data, ensuring a comprehensive understanding of the impact of immersive technologies.

1.9.5 Chapter 5: VR Workshop Experiment

Chapter 5 focuses on the analysis of data collected from surveys, interviews, and case studies. It presents findings on the effectiveness of VR in enhancing the learning experience and communication in design studios.

1.9.6 Chapter 6: AR Workshop Experiment

Chapter 5 focuses on the analysis of data collected from surveys, interviews, and case studies. It presents findings on the effectiveness of AR in enhancing the learning experience and communication in design studios.

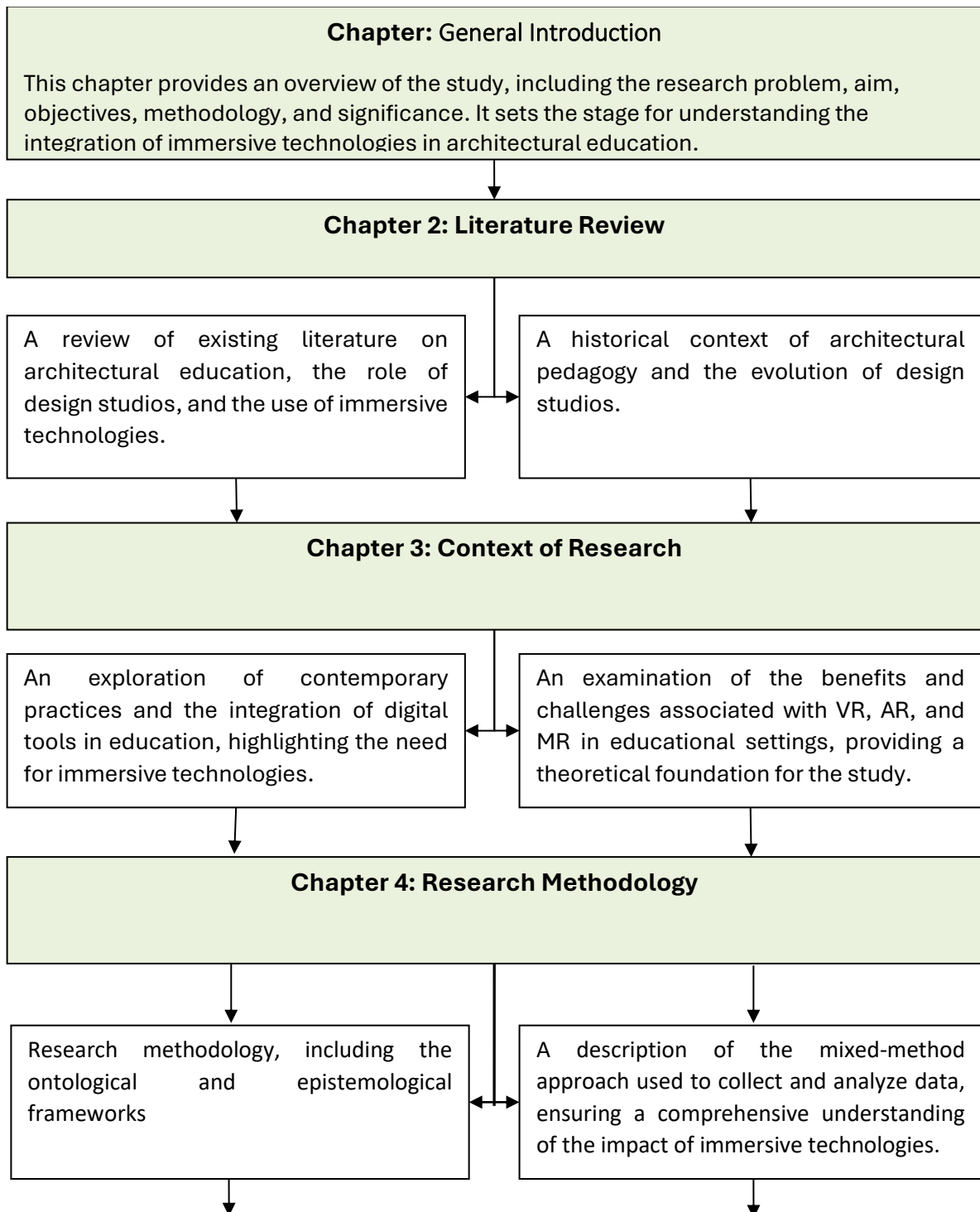
1.9.7 Chapter 7 MR Semester Experiment

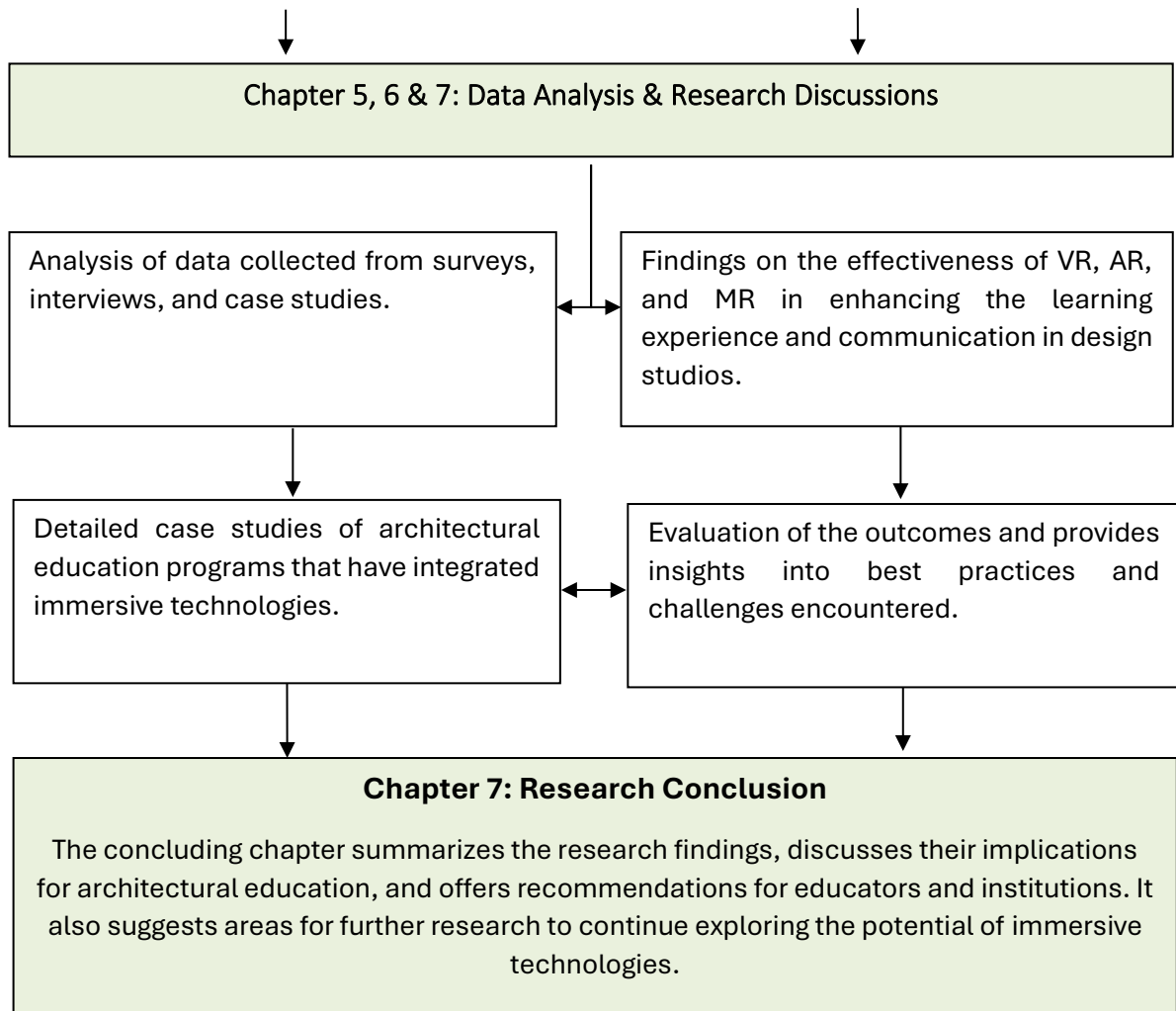
Chapter 5 focuses on the analysis of data collected from surveys, interviews, and case studies. It presents findings on the effectiveness of MR in enhancing the learning experience and communication in design studios.

1.9.8 Chapter 8: Research Conclusion

The concluding chapter summarizes the research findings, discusses their implications for architectural education, and offers recommendations for educators and institutions. It also suggests areas for further research to continue exploring the potential of immersive technologies.

Figure 1.10: *The Structure of Thesis*





Chapter 2: LITERATURE REVIEW

2.0 Introduction

The evolution of architectural education is marked by significant shifts in pedagogical approaches, driven by technological advancements and changing societal needs. This chapter delves into the historical, traditional, and contemporary periods of architectural pedagogy, examining how each era has shaped the design studio—the heart of architectural education. From the classical period's master-apprentice model to the contemporary era's technologically enriched environments, this literature review explores the continuous transformation of teaching methods and their impact on design education. The integration of immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) represents the latest frontier in this ongoing evolution, promising to revolutionise the way architectural concepts are taught and experienced. This chapter aims to provide a comprehensive overview of these transitions, setting the stage for a deeper understanding of how immersive technologies can further enhance architectural pedagogy. This examination of immersive technologies' role in architectural pedagogy directly aligns with the study's objective of determining how these technologies enhance creativity, collaboration, and student engagement in the design process.

2.1 The Classical Period

The classical period of architectural education is characterised by the emergence of the design studio model, rooted in the apprenticeship system. During this time, the studio environment began to take shape, influenced by the practices of the Ecole des Beaux-Arts in Paris (Carlhian, P, J., 1980). This institution formalised architectural education, combining theoretical instruction with practical experience in a studio setting. Integrating design work into a shared studio space allows for a more collaborative and immersive learning experience, laying the foundation for modern architectural pedagogy (Chafee, 1977; Egbert, 1980).

2.1.1 The Design Studio

The classical period of architectural pedagogy is when the first instance of recorded studio-based design learning takes place. Studio-based learning originates from the École des Beaux-Arts and the medieval guilds' apprenticeship system, where apprentices developed skills and knowledge from their masters. This dual learning model incorporated theoretical learning in the classroom and practical skills in the workplace (Broadbent, 1995). As mentioned previously, studio design teaching and its formation are essential for understanding architectural pedagogy.

The École des Beaux-Arts curriculum became the model for the first formalized schooling system, blending artistic and technical knowledge. This curriculum influenced the creation of a structured approach to architectural education, evolving into today's studio model. The Ecole itself had its roots in the Academie Royale de Peinture et de Sculpture and the Academie Royale d'Architecture, the latter of which was established by Louis XIV in 1671 to share knowledge and opinion and which had a limited elite teaching role (Chafee, 1977). A fundamental intention behind the Academie was to formalise architecture within a structured professional institution. However, the widespread operation of 'ateliers' in which architects worked with their apprentices compromised its operation. Design work tended to be undertaken by students within the ateliers themselves, and thus remotely from the Academie where lectures were attended and where it was intended that all learning takes place. The 'ateliers' is more commonly known as the master and apprenticeship model. The studio model of today was in its infancy stage within this period. Integrating design work into shared space, or 'studio space,' begins to occur in later years.

2.1.2 The Seeds of Design Studio

French architect Jean-Francois Blondel sought to address this problem of disaggregation within the education system through the foundation of a new curriculum for the École des Arts in 1740. Blondel intended to provide all necessary aspects of learning in one location to avoid the compromise mentioned earlier (Egbert, 1980). This curriculum introduced a full-time regime whereby students studied a comprehensive program six days a week, which significantly shaped modern architectural education.

This new approach emphasized the development of expertise in real-world settings, aligning practical experience with academic learning. The seeds of the contemporary studio environment were planted here, as students had broad academic resources while engaging in hands-on activities. The teaching method became the foundation for today's architectural education, including design studios as a core element.

The École des Beaux-Arts curriculum was divided into three stages: 'aspirant,' 'eleves,' and 'diplome' levels, and was founded on the following principles:

- Division of students into 'ateliers' (the root of the current 'unit' systems)
- Senior students were used to help tutor 'aspirants'
- Design was taught by practicing architects
- Design teaching spanned the entire period of study
- 'Esquisse' exercises were routinely undertaken

Projects were organized as 'Concours' or 'Charettes' and were judged by 'juries' or academics and practitioners. These principles, practices, and terminologies largely persist in contemporary architecture education, with the Beaux-Arts system having been exported to the UK, USA, and other parts of the globe. Blondel's vision to combine theoretical knowledge with hands-on application remains influential in contemporary

design studios. In this way, the atelier or studio system founded in the Beaux-Arts became internationally adopted (Harbeson, 1927).

2.1.3 Impact of Industrialisation

In addition to the advancements in technology and construction of the 18th century, rampant industrialisation that dominated the century has also contributed to a shift in the educational paradigm in establishing formal schools and developing institutional curricula. Rather than the individualistically based studies typified by the master-apprentice relationship of the atelier, the institutional curricula were more successful in addressing the ever-growing knowledge within the profession. Therefore, architects from institutional backgrounds were more adaptable, efficient and thriving in the industrial era. The pedagogy employed at this time had developed from the ethos of enlightenment and the belief that humanity had an insatiable desire to further knowledge and capability. This approach has been described as 'encouragement pedagogy' (Pfammatter, 2000, p. 10).

The principal teaching method deployed in the Ecole des Beaux-Arts under Jean Nicholas-Louis Durand, leader of the school at the end of the 18th century, revolved around the study of building typologies. Instead of relying solely on the master-apprentice model, institutionalized curricula became essential for adapting to the growing complexity of the architectural profession. Architects who were trained through institutional systems proved more adaptable and efficient in the industrialized world. These typological studies involved the systematic analysis of different building types based on their functional requirements and aesthetic principles. Students were encouraged to explore the relationship between form and function, incorporating problem-solving techniques to address practical challenges such as structural integrity, materials usage, and spatial organization.

Problem-solving was central to this approach, as students were tasked with designing buildings that adhered to predefined categories—such as religious, civic, or residential—while addressing the unique technical and aesthetic demands of each. This shift marked the beginning of a more analytical approach to design, where the 'problem-types' methodology emerged, focusing on the specific constraints and requirements of various building forms. The study of typologies formed the dominant methodology for approximately 150 years. It was not until around 1960 that architecture education experienced a shift in emphasis to a focus on a new problem-solving and 'problem-types' attitude (Lackney, 1999). This is where there is a clear end to the classical and a complete transition to the traditional period of architectural pedagogy. Afterwards, Schon's work and the inspiration his work provided, gave tremendous insight that strengthened the foundations of traditional pedagogy for the following years.

2.1.4 Slow Decline of Apprenticeship Model

The Ecole des Beaux-Arts model was introduced to the UK and US at the end of the 19th Century. However, apprenticeship or 'articled pupillage' was still the sole means to professional qualification at the end of the 18th century (Stevens, 1998, p.174). This old tradition had its roots in the work of the philosopher and educator John Locke, who published 'Some Thoughts Concerning Education' in 1693 (Locke, J., 1990). In his work Locke made significant arguments for the integration of practical and commercial endeavour to theoretical study. These ideas shaped the education system in the UK for over a century, blending hands-on experience with theoretical knowledge. Locke's arguments coupled with ideologies of the Ecole des Beaux-Arts extending across the Channel at the time formed the cornerstone of the educational process for the following two centuries (Crinson and Lubbock, 1994).

While the École des Beaux-Arts curriculum made strides in formal education, it took time for the apprenticeship system to decline. During the 17th and 18th centuries, architects primarily learned through hands-on experience in the workplace, with relatively little formal theoretical instruction. This created a significant gap between the educational and professional worlds. It wasn't until the early 20th century that the process of fully integrating architectural education into academic institutions gained momentum. Even then, the apprenticeship system persisted in various forms, highlighting the long-standing tension between practical training and academic instruction in architecture. The classical apprenticeship model continued to dominate in the UK until around 1900, but by the mid-20th century, institutional education had largely replaced it. During this transition period, the 'values and rewards' of the two approaches have never operated in harmony. (Boyer and Mitgang, 1996, p.9). The differences of the approaches were the subject of much discourse and criticism between architectural community in early years. The differences between these approaches were the subject of much debate within the architectural community. Over time, figures such as Donald Schön helped to solidify the value of traditional pedagogy, portraying it as more efficient in both the practice and academic worlds.

2.1.5 The German Bauhaus System/Journeyman Approach

Meanwhile in Europe, the establishment of the German Staatliche Bauhaus in 1919 constituted a challenge to the highly prescriptive Beaux-Arts classical system, but regardless the presence and notion of the design studio was never critiqued or questioned. The Bauhaus sought to conserve the idea of the apprentice master system or sometimes referred as 'journeyman' approach. More specifically, within the Bauhaus students were expected to develop expertise through exposure to 'real' scenarios, technologies, and production processes. Unlike the Beaux-Arts system, which relied heavily on theoretical and classical architectural education, the Bauhaus emphasized

learning by doing, with a strong focus on practical craftsmanship. The Bauhaus believed that students should experience real-world production processes, which would equip them with high levels of competence in synthesis, aesthetic judgment, and design thinking. This new problem-solving approach became the hallmark of Bauhaus graduates (Lackney, 1999). Bauhaus students worked directly with materials, learning the practical and technical aspects of building design, which contrasted with the more abstract, artistic focus of the Beaux-Arts. This method aimed to break down the divide between art and industry, combining craftsmanship with modern technology. Interestingly, this problem-solving approach resurfaced in much later years and influenced contemporary pedagogic models.

2.1.6 Issues of Running Obsolete Education Methods

Palermo (1996, p.12-13) provocatively asserts that, 'We are operating a 1900-year-old education program directed toward delivering a 500-year-old model architect as we head into the 21st century.' This statement presents a harsh critique of both the architectural profession and the education system that sustains it, arguing that architectural pedagogy has failed to evolve in alignment with contemporary socio-political, economic, and technological contexts. While this represents an extreme perspective, there is substantial discourse in architectural education that supports the need for reform (Schön, 1983; Salama & Wilkinson, 2007).

Schön (1983) famously criticized the inertia of traditional design-studio models, arguing that they often emphasize a master-apprentice dynamic that is resistant to change and does not sufficiently incorporate technological advancements or interdisciplinary approaches. More recent literature reinforces this concern, highlighting issues of accessibility, outdated assessment methodologies, and the slow adoption of digital tools

and immersive technologies in architectural curricula (Salama & Wilkinson, 2007; Drach & Boud, 2021).

Thus, while Palermo's assertion is deliberately provocative, the underlying concern is relevant: traditional architectural education struggles to keep pace with contemporary design methodologies, digital innovations, and evolving industry demands. This research further explores this argument by examining how immersive technologies can bridge the gap between historical pedagogical models and modern architectural practice, ensuring that education remains responsive to the needs of 21st-century architects.

The core of the argument is that architectural education has been relatively impervious to developments in art and design education, despite sharing similar studio-based teaching structures. However, modern architectural practice has evolved dramatically, and educational methods must reflect this evolution. The growing influence of digital tools, sustainability concerns, and interdisciplinary collaboration challenges the traditional architectural curriculum. Palermo highlights the disconnect between the practice of architecture and the education provided, suggesting that current methods do not sufficiently address contemporary needs and technologies. In his work Palermo further supports his view by stating that architectural education appears to have been relatively impervious to developments in art and design education, with which it shares the ethos of studio-based education. The reasoning behind major reformations and transitions was the very same one that Palermo conveys in his work. When the education does not reflect and integrate the events of contemporary practice it begins to alienate itself from the field and diminish its efficiency.

The notion of 'obsolete' education reflects the ongoing tension between historical teaching methods and the evolving demands of modern architectural practice. Palermo (1996) critiques the persistence of traditional pedagogical models, arguing that they

remain rooted in outdated master-apprentice dynamics and fail to fully incorporate technological advancements, environmental considerations, and interdisciplinary collaboration. While Palermo's view is provocative, it resonates with broader discussions in architectural education that highlight the slow adaptation of curricula to emerging challenges (Schön, 1983; Salama & Wilkinson, 2007).

However, it is important to recognize that the design studio model is not solely focused on aesthetic outcomes. While visual and spatial composition remains a core aspect of architectural judgment, contemporary studios also assess sustainability, structural feasibility, and user-centered design principles (Drach & Boud, 2021; Williams, 2017). The tension in architectural education, therefore, lies not in a binary opposition between aesthetics and technical considerations but in the challenge of balancing multiple, often competing, educational priorities.

As academia, the profession, and the broader educational system continue to evolve, there is an increasing emphasis on integrating digital tools, immersive design methods, and sustainability-driven pedagogies into studio-based learning. This study explores how such adaptations can preserve the strengths of traditional architectural education while ensuring its relevance to contemporary practice.

The trinity of architectural academia, the profession, and the broader education system presents numerous challenges, not only in achieving equilibrium between academic and practical demands but also in maintaining vision and agility as the profession evolves. Steele (2004) argues that architecture schools, despite being relatively young in historical terms, have settled into increasingly stable and inert forms, raising concerns about their ability to adapt to the multiple forces reshaping the way architects live, work, and learn (Steele, 2004, p.71).

There is evidence of this evolution in recent years, particularly in the UK, where alternative routes into the architectural profession have emerged. The introduction of Degree Apprenticeships in Architecture, launched by the Royal Institute of British Architects (RIBA) in partnership with industry stakeholders, provides an alternative to the traditional five-year academic model. Degree apprenticeships allow students to gain practical experience within professional firms while studying part-time, ensuring a more integrated learning approach that aligns with contemporary industry needs (RIBA, 2019).

Additionally, the rise of digital and computational design methodologies has influenced curriculum structures, pushing architecture schools to incorporate new technologies, interdisciplinary collaborations, and sustainability-focused education to remain relevant (Drach & Boud, 2021). These adaptations, while not entirely dismantling the traditional studio model, suggest a growing recognition that architectural education must evolve to meet technological advancements, industry expectations, and socio-political pressures.

Steele's argument remains relevant in this context: while architecture schools continue to play a central role in shaping the profession, their long-term viability will depend on their ability to embrace alternative pathways, technological integration, and pedagogical flexibility. This study explores how such shifts, particularly through the incorporation of immersive technologies, may contribute to the ongoing evolution of architectural education, ensuring that it remains responsive to the needs of contemporary practice.

In today's architectural profession, stagnation arises from the continued reliance on outdated methods that do not fully embrace emerging technologies such as immersive reality, artificial intelligence (AI), and advanced computational tools. The introduction of Computer-Aided Architectural Design (CAAD) initiated a shift toward digital design, but its impact has primarily been felt in larger firms with greater access to resources. Smaller studios, which often lack the infrastructure for full digital integration, have been slower

to adopt these tools, creating a disparity between firms at the forefront of design innovation and those maintaining traditional practices.

Compared to other disciplines within higher education institutions, architecture's adoption of AI remains relatively slow and fragmented. Fields such as medicine, business, and data science have embraced AI-driven methodologies at an accelerated pace, leveraging machine learning, predictive analytics, and automation to enhance efficiency and decision-making (Nguyen & Holmes, 2021). In engineering disciplines, AI has been deeply integrated into simulation models, optimization processes, and material analysis, enabling faster prototyping and structural innovations (Wang et al., 2022). In contrast, architecture has been more cautious in adopting AI, largely due to the discipline's emphasis on creative intuition, iterative problem-solving, and human-centered design, which resist full automation (Celani & Vaz, 2020).

Despite AI's potential for generative design, energy simulations, and automated spatial analysis, architectural education has struggled with structural barriers to integration. These include the dominance of traditional studio-based pedagogy, a slower curriculum adaptation cycle, and limited faculty expertise in computational design and AI-driven workflows (Brell-Cokcan & Braumann, 2019). While leading architecture schools and research labs are actively exploring AI applications, its widespread incorporation into architectural education remains uneven, reflecting a broader disciplinary hesitation toward fully automated design processes.

The evolution of digital tools in architecture presents a continuum rather than a sharp transition between paradigms. Computer-Aided Architectural Design (CAAD) introduced digital drafting and parametric design, allowing architects to move beyond hand-drawn representation. Building Information Modeling (BIM) expanded upon this by integrating data-driven design, collaborative workflows, and lifecycle management, creating a more

intelligent and interconnected approach to building design. AI, however, represents a new dimension of computational design, moving beyond automation and digitization to autonomous decision-making and generative creativity.

Unlike CAD, which primarily aids in digital drafting, or BIM, which centralizes building data for efficiency, AI introduces the ability to predict design outcomes, optimize form-finding processes, and learn from vast architectural datasets. This raises fundamental questions about the role of the architect: where does human agency end, and where does algorithmic generation begin? While BIM systems have been widely adopted in practice due to their structured data-driven approach, AI remains more experimental and less standardized, further contributing to architecture's cautious adoption of this emerging technology.

As AI continues to reshape multiple disciplines, architecture must critically evaluate its potential and limitations in education and practice. While the profession has begun integrating AI-driven parametric design, environmental modeling, and generative algorithms, further efforts are required to bridge the gap between traditional architectural methodologies and data-driven computational tools. This study explores how immersive technologies can act as an intermediary step, helping educators transition from fully manual design workflows to AI-enhanced generative approaches, ensuring that technological innovation is meaningfully integrated into architectural pedagogy.

Looking forward, immersive technologies, AI, and BIM are poised to play a pivotal role in transforming architectural education and practice. These technologies collectively offer new ways of conceptualizing, analyzing, and interacting with design, breaking away from traditional 2D representation and static models toward more dynamic, data-driven, and experiential processes.

BIM already represents a fundamental shift in architectural workflows by integrating design, construction, and lifecycle management into a unified digital model. It provides architects with parametric control, data-informed decision-making, and multi-disciplinary collaboration, ensuring that buildings are not only designed aesthetically but also evaluated in terms of performance, sustainability, and efficiency. However, BIM remains largely analytical and data-centric, functioning within structured modeling parameters.

In contrast, immersive technologies such as VR, AR, and MR extend BIM's capabilities by allowing architects to inhabit and interact with spatial models at a full scale. This bridges the gap between abstracted digital models and embodied spatial experience, enabling real-time design validation, stakeholder engagement, and experiential learning. Similarly, AI enhances both BIM and immersive workflows by introducing generative design, predictive analytics, and automation, enabling architects to explore design options beyond manual parametric adjustments.

Thus, rather than being separate trajectories, BIM, immersive technologies, and AI represent a continuum of digital transformation in architecture. BIM provides the data structure, immersive technologies provide spatial experience and interaction, and AI introduces intelligent decision-making and optimization. Together, they redefine architectural education and practice by moving from static digital representation to an adaptive, interactive, and predictive design process.

As these tools become more accessible, the industry can no longer remain inert; both education and practice must adapt to keep pace with the digital revolution. Just as technical advances formalized architectural education in response to industrialization, the rise of immersive technologies and AI represents the next frontier that requires

architects to rethink their approach to design and collaboration. Research indicates that digital transformation in architecture is accelerating, with AI-driven generative design, virtual prototyping, and real-time spatial simulation reshaping industry expectations (Celani & Vaz, 2020; Drach & Boud, 2021). This shift necessitates a reassessment of pedagogical models to ensure that graduates possess the digital competencies required for contemporary practice (Salama & Wilkinson, 2007).

Architecture education is at a critical juncture, where the incorporation of these technologies is no longer optional but essential for maintaining relevance in an evolving profession. Studies have highlighted gaps in traditional architectural education, particularly regarding the limited integration of computational design, parametric modeling, and real-time environmental analysis (Williams, 2017; Brell-Cokcan & Braumann, 2019). The continued reliance on studio models focused predominantly on aesthetic outcomes has been criticized for failing to incorporate environmental sustainability, technological literacy, and globalized design strategies (Schön, 1983; Salama & Wilkinson, 2007).

Immersive technologies and AI address these gaps by enabling spatial cognition, real-time collaboration, and performance-based design iteration, ensuring that students engage with responsive, data-driven workflows rather than static representation (Celani & Vaz, 2020). As industry demands shift toward computational intelligence, interdisciplinary teamwork, and predictive analytics, architectural education must re-evaluate core methodologies to align with these expectations. By integrating VR, AR, and AI-enhanced design processes, educators can bridge the gap between historical design traditions and future-oriented professional practices, fostering a curriculum that is both innovative and technologically adaptive (Drach & Boud, 2021).

2.1.7 Complexity in Delivering Architectural Education

'Architecture is a complex socio-technical field and requires both training in a number of skills and knowledge as well as an education to cultivate broader, less utilitarian and more extensive skills and knowledge. As such, architecture is and should be an area of both education and training' (Teymur, 1992, p.88). Ever since the introduction of a formalised education structure, further tensions have surfaced and persisted between the profession and the academy regarding the true purpose and focus of architectural education.

The 'Oxford Conference', held in April 1958 was the first educational conference held in the UK since 1924, and was the most influential event for traditional pedagogy. At this conference it had been agreed that architectural education should reside within the university structure supporting and driving forward the transition to traditional pedagogy. The fundamental stimulus of the conference came from a desire to improve what was seen as low-quality architectural design.

The complexity of architectural education lies not only in its technical aspects but also in its interdisciplinary nature. Students must master a wide range of subjects, from structural engineering and materials science to environmental design and urban planning. This breadth of knowledge is essential to the profession, but it also creates challenges for educators tasked with delivering such a diverse curriculum.

Furthermore, the rapidly changing landscape of the architectural profession and its relationship with Higher Education adds another layer of complexity. As new technologies and methodologies emerge, educational programs must be agile enough to adapt, not only to meet industry demands but also to serve as an incubator of innovation.

Rather than simply responding to practice, Higher Education plays a dual role—on one hand, it injects new skills and knowledge into the profession, particularly benefiting

smaller, less-resourced firms that may struggle to integrate emerging technologies independently. On the other hand, larger firms—often at the forefront of digital and technological adoption—sometimes express frustration with the disconnect between academia and real-world project workflows (Drach & Boud, 2021). This highlights the complex interplay between education and practice, where architectural pedagogy must balance the need for foundational learning, research-driven exploration, and industry-relevant skill development (Salama & Wilkinson, 2007).

The integration of digital design tools, sustainability concerns, and globalized architectural approaches requires continuous curriculum revision, yet these changes often create friction between traditional pedagogical methods and the diverse demands of practice. The tension does not lie solely in academia's response to professional expectations but also in the profession's diverse and sometimes competing needs, from innovation-driven digital firms to smaller studios reliant on foundational architectural skills. Recognizing these nuances is crucial for ensuring that architectural education remains both visionary and practically relevant.

During this period, prior to the conference, the number of student entrants to the profession coming through the classical apprentice route were almost the same as those coming through the university system (Crimson and Lubbock, 1994). University-based education was advocated to be the means by which the corpus of knowledge particular to the profession could be advanced, and arguments were promoted for raising entry standards to education.

In the twentieth century, throughout much of the Western world, architecture was consigned to the margins within the university system, sitting as it does outside the dominant research-based model developed from the sciences (Martin, 1959). Indeed, until very recently, institutional education has continued to be dominated by

practitioners, as opposed to academics in the classical sense (Hawley in Chadwick, 2004). The result has been that as a discipline it has suffered from low levels of understanding from an institutional perspective.

Design studio, in particular, is a form of teaching that is poorly understood by academia. In Schon's terminology it is 'deviant' in its relationship to the historic apprenticeship model, and the epistemology of practice. Elsewhere, where the dominant paradigm of professional learning embodies an epistemology of practice rooted in the contemporary research-oriented institution, professional knowledge and competence relates to a 'normative professional curriculum' (Schon, 1985, p.5).

The complexity of delivering architectural education arises from the ongoing tension between technical and theoretical knowledge and the evolving demands of the profession. Architectural education must prepare students to master technical competencies, engage in critical design thinking, and respond to real-world challenges, all while keeping pace with the rapid integration of new technologies, sustainability imperatives, and global design practices (Salama & Wilkinson, 2007). This tension has led to long-standing debates over the balance between traditional studio-based learning and the need for digital, interdisciplinary, and research-driven approaches (Schön, 1983; Drach & Boud, 2021).

The increasing complexity of architectural projects, which now require expertise in environmental simulation, computational design, and data-driven decision-making, means that a rigid, one-dimensional approach to education is no longer viable (Celani & Vaz, 2020). Instead, architectural pedagogy must embrace flexible, multidisciplinary models that integrate technical expertise with theoretical knowledge, digital innovation, and collaborative problem-solving (Brell-Cokcan & Braumann, 2019).

This discussion is central to the overall argument of the thesis because it highlights the importance of adapting educational models to reflect current and future trends in architecture. A growing body of research suggests that immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) offer solutions to these pedagogical challenges by allowing students to:

Visualize and interact with complex spatial designs in real-time (improving spatial cognition).

Engage in iterative, experiential learning (bridging the gap between theory and practice).

Enhance interdisciplinary collaboration (connecting students with engineers, urban planners, and other professionals remotely).

By integrating immersive technologies, architectural education can bridge the divide between abstract conceptual thinking and applied design practice, ensuring that students are better equipped for the technological and methodological shifts shaping the profession. This rationale underpins the thesis by demonstrating that a flexible, multidisciplinary approach is essential not only for educational innovation but also for maintaining architecture's relevance in a rapidly changing professional landscape.

Immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) introduce interactive and experiential ways for students to engage with architectural design processes. Unlike traditional 2D drawings and static models, these technologies enable students to inhabit and manipulate digital spaces in real-time, fostering a deeper spatial understanding and iterative design thinking (Celani & Vaz, 2020).

By integrating immersive environments into the curriculum, students can engage in real-world architectural applications such as:

- Client communication and stakeholder engagement: VR allows students to present and walkthrough designs in full scale, improving their ability to convey architectural intent effectively.
- Sustainable and performance-driven design: AR and MR support real-time environmental analysis and energy modeling, helping students make informed design decisions regarding sunlight exposure, ventilation, and material efficiency (Brell-Cokcan & Braumann, 2019).
- Construction workflows and collaborative design: MR applications bridge the gap between digital and physical construction by overlaying digital blueprints onto real-world sites, enhancing precision and reducing errors in the transition from design to construction.

Through these capabilities, immersive technologies better prepare students to tackle contemporary architectural challenges, including sustainable urban development, interdisciplinary collaboration, and the increasing digitization of the architectural profession. By providing a more intuitive, interactive, and data-driven design experience, these tools equip students with the skills necessary to navigate the evolving landscape of architectural practice.

2.1. 8 Traditional Versus Contemporary Pedagogy

Architecture has long been a subject taught through traditional methodologies, with the studio-based learning model being a dominant feature of its pedagogy. The design studio, as a space for creative thinking, critique, and iterative development of ideas, is a hallmark of architectural education, and its roots go back to the École des Beaux-Arts and earlier apprenticeship models. However, as the profession and its needs have evolved, so too have the methods of teaching.

Traditional pedagogy, focused on the transmission of knowledge from teacher to student and the development of aesthetic and technical skills, was largely centred on the master-apprentice model and later the Beaux-Arts studio system. While effective in its time, this approach does not fully accommodate the demands of the contemporary architectural profession, where interdisciplinary collaboration, technological integration, and globalized design strategies are increasingly important.

Contemporary pedagogical models in architecture must adapt to include a broader understanding of the context in which architectural practice occurs. Today's students must be equipped with not only design skills but also the ability to work with advanced digital tools, engage with sustainability concerns, and navigate complex, globalized projects. Contemporary education emphasizes critical thinking, problem-solving, and the use of technology to simulate real-world environments.

Immersive technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) offer students new ways to interact with their designs in real time. These tools allow for more intuitive exploration of spatial relationships, materiality, and user experience, bridging the gap between theoretical knowledge and practical application. By integrating these technologies into the curriculum, architectural education can become more aligned with the realities of the profession.

The shift from traditional to contemporary pedagogy is not merely about adopting new tools but also about fostering new ways of thinking. The design studio remains central to architectural education, but its role is evolving to accommodate immersive technologies and interdisciplinary collaboration, ensuring that students are prepared to meet the challenges of 21st-century architecture.

2.2 Traditional Period

The 'traditional' period refers to the time when architectural education transitioned away from the Beaux-Arts and apprenticeship models and became more institutionalized within universities. This period spans from the early 20th century to the late 1960s, a time of significant global change, both socially and technologically. During this time, architecture as a profession became more standardized, and the role of the architect evolved to meet the needs of a rapidly urbanizing world.

In the traditional period, architectural education began to focus more on theoretical knowledge and research-oriented instruction, which was seen as essential for responding to the growing complexity of urban planning and technological advancements. This period also saw the formalization of design studios within university curricula, where students engaged in both individual and collaborative design projects, but with a more structured approach than in previous models.

The Bauhaus, in particular, had a significant influence during this time, advocating for a holistic approach to design that integrated art, craft, and technology. This period represented a shift toward a more analytical and structured way of thinking about architecture, where problem-solving and technical precision became as important as aesthetic considerations. This era was heavily influenced by the works of educators like Donald Schon, who emphasized reflective practice and experiential learning within the design studio. The introduction of formal architectural schools provided a structured environment for students to engage in both theoretical and practical aspects of architecture. This period also highlighted the importance of integrating diverse disciplines into the studio, fostering a holistic approach to architectural education (Schon, 1983; Collins, 1979).

Architectural education during this time also began to incorporate elements of modernism, reflecting the social and cultural changes happening globally. The focus on functionality,

simplicity, and the rejection of ornamentation became central themes in both architectural practice and education, as seen in the works of key figures such as Le Corbusier and Ludwig Mies van der Rohe. This emphasis on modernism further shaped the architectural curriculum, encouraging students to embrace the evolving architectural landscape while retaining strong design fundamentals.

2.2.1 Pressures of Practice

Pressures in the private practice sector are often dictated by finance, competition, and technology (Mayo, M, J. and Cuff, D., 1992; Vos, B, M., Wamelink, H. and Volker, L., 2016). These pressures are reflected and need to be addressed within the education sector. The rapid and constant change of technology and design in the practice sector naturally dictates the demands in the education sector. Therefore, to be able to adapt to the changes and development in practice the education sector shall in every revolution demand agility, adaptability and efficiency in design and delivery of learning within respective fields (Fang, Y., 2014). Equally, as part of this process, it requires an ability to objectively reflect on and appraise the suitability and effectiveness of adopted methods and pedagogies. The most dramatic revolution and reflectance occurs during the shift from classical to traditional pedagogy.

The shift from Classical Pedagogy to Traditional Pedagogy represents one of the most transformative periods in architectural education. Classical Pedagogy was characterized by a dual approach: on one hand, it relied heavily on lecture-based learning and theoretical knowledge acquisition, prioritizing rote memorization, hierarchical instruction, and passive learning. However, in architecture and other craft-based disciplines, practitioner-based learning was equally significant, with students learning through a Master & Apprentice model. This hands-on mentorship allowed students to observe, replicate, and refine their skills under the direct guidance of an experienced

practitioner, ensuring that technical and conceptual knowledge was passed down through direct engagement in real-world practice (Schumacher, 2021; Piątkowska, 2020).

In contrast, Traditional Pedagogy, particularly within architectural education, introduced studio-based learning—a model that emphasized active engagement, critical reflection, and hands-on design practice. This transition represented a dramatic revolution as it fundamentally redefined the learning experience, shifting from a Master & Apprentice dynamic and rigid theoretical instruction to an interactive, iterative design process. The introduction of studio culture, where students work in collaborative environments under tutor guidance, marked a departure from structured apprenticeship models toward a more exploratory and problem-solving approach, where knowledge was co-constructed rather than simply transmitted (Masdéu & Fuses, 2021).

This transformation was revolutionary because it not only changed the way knowledge was transmitted but also reshaped the cognitive and creative development of students. The shift required both educators and students to adopt a more exploratory, reflective, and participatory role in learning, fostering an educational environment where design thinking, problem-solving, and spatial awareness became central to architectural pedagogy. The move away from rigid classical frameworks allowed for greater flexibility, creativity, and real-world applicability, paving the way for modern educational methodologies and, eventually, the integration of immersive technologies (Masdéu & Fuses, 2021; Piątkowska, 2020).

2.2.2 Classical to Traditional

Traditional pedagogy, its beginning as a formal institutional structure shifting from classical apprenticeship takes root early in the 20th century due to the written works of Arthur Cates (Cates, A., 1893). The long-time campaigner for formal architectural

education described the classical system as under pressure due to” ...the stress and struggle of modern life, the wide range of knowledge and acquirements now necessary to ensure success and the changed relationship between master and pupil.” (Cates, 1900, p.394). As the architectural field became more complex, it was clear that the knowledge required to train architects could no longer be contained solely within the master-apprentice relationship. The increasing breadth of knowledge—from technical skills to design theory—necessitated a shift to a more collective, institutionalized form of education. This institutional approach allowed multiple experts within an institution to contribute their specialized knowledge to the student’s education, filling the gaps left by the limitations of the master-apprentice model.

The classical apprentice and master system of pupillage no longer seemed to be an efficient way of raising architects since the pupil/ student is mostly limited to what they can acquire from their master and will not have sufficient amount of hard knowledge. Though schools of architecture at the time existed, these schools still followed an apprenticeship approach. Arthur Cates’s views were echoed by William Emerson (1901, p.1) RIBA President in 1900, who called for a ‘better and more methodical system of Education for our students in architecture’.

The studio model, which became central to architectural education during the traditional period, represents a significant departure from the master-apprentice dynamic. A studio model is a creative and collaborative environment where students work on design projects that integrate knowledge from diverse fields such as structures, construction, humanities, and environmental studies. It acts as a forum where students can apply theoretical knowledge to real-world problems. By bringing together expertise from various disciplines, the studio fosters creativity and innovation, allowing students to experiment and explore solutions in a guided setting.

The architectural studio model is widely recognized as the core learning environment in architectural education, where students develop both creative and technical competencies through iterative design processes. Scholars such as Schön (1983) and Salama & Wilkinson (2007) have emphasized that the design studio is not merely a place for producing aesthetically refined designs, but rather a space where integrated learning occurs, combining critical thinking, problem-solving, and technical application.

In this environment, students are encouraged to think critically and approach design holistically, considering the social, technical, and environmental implications of their work. The studio bridges the gap between theory and practice, enabling students to engage in project-based learning that mirrors the complexities of real-world architectural challenges (Drach & Boud, 2021). This structure supports a problem-solving approach to design, where students engage in collaborative, interdisciplinary discussions that reflect professional workflows.

Thus, rather than simply being a creative workspace, the design studio serves as a dynamic educational setting that fosters experiential learning, critical reflection, and the integration of technical and artistic knowledge. This conceptualization aligns with established pedagogical research and forms the basis for exploring how immersive technologies can further enhance this learning model by introducing real-time spatial analysis, interactive collaboration, and data-driven design experimentation.

The classical studio model, present during the traditional period, was still rooted in the master-apprentice system but was now more formalized within universities. However, the studio began evolving into a space where knowledge from various fields could be integrated. For example, in France, the studio model was applied alongside other art and design disciplines (Ballon & Wittman, 1996), where aspiring architects attended workshops with sculptors to develop the skills necessary for conveying architectural

ideas. This studio environment demonstrated that the integration of diverse skills and disciplines was crucial for architectural education, marking the shift from the classical model of isolated master-apprentice learning toward a more collaborative and holistic system of education (Peter Collins, 1979).

2.2.3 Reflection in Traditional Pedagogy

In Donald Schön's *The Reflective Practitioner*, the design studio model is acclaimed as a learning medium and the cornerstone of architectural education. This reverence for the studio remains true in contemporary education, where it continues to play a central role.

Professional accreditation bodies such as the Architects Registration Board (ARB) and the Royal Institute of British Architects (RIBA) mandate that at least 50% of an accredited architectural curriculum must focus on design-related education (RIBA, 2021). While this requirement encompasses a range of design-focused learning activities, including technical, theoretical, and interdisciplinary components, the design studio remains the primary pedagogical model through which design education is delivered. The studio provides an integrated space for problem-solving, creative exploration, and applied learning, reinforcing architectural competencies that extend beyond aesthetic design into technical, environmental, and social dimensions.

This institutional backing highlights the central role of the design studio in shaping the key attributes that architects must develop, ensuring that students engage in experiential, iterative, and reflective learning processes that align with both academic and professional expectations.

The studio provides a dynamic environment where students can engage in creative problem-solving and apply integrated learning. The key attributes developed in the studio model include critical thinking, creativity, problem-solving, and the ability to synthesize knowledge from various fields such as structures, environmental studies, and

construction techniques. This interdisciplinary collaboration is essential in contemporary pedagogy, as students are expected to navigate complex, real-world scenarios.

The fundamental approach to teaching through the studio model has been adopted universally, and its global presence, along with its lineage, is remarkable. Although the design studio has evolved, it still embodies certain elements of the master-apprentice approach, where students receive guidance from tutors and practitioners. However, the studio model provides students with exposure to a broader palette of materials and knowledge through lectures, seminars, and external experts, allowing them to incorporate this diverse information into their design work. This fusion of applied learning and external knowledge is key to how contemporary design studios function (Schon, 1983).

Despite the flexibility of the studio model, the transition to contemporary education has not been entirely smooth. The profession itself faces numerous challenges, including sustainability concerns, technological advancements, and increased pressure on resources. These challenges often require students to adopt new ways of thinking about design, pushing them to integrate digital and immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR). These technologies provide students with new ways to visualize and engage with their designs, fostering a deeper understanding of space and user experience.

Traditional studio models have long been praised for fostering deep engagement through hands-on collaboration, direct tutor-student interaction, and peer learning. However, these models also have inherent limitations, particularly in terms of accessibility, real-time design iteration, and exposure to diverse design methodologies. Without integrating modern technology, students may experience a more constrained learning environment,

where design exploration is limited to physical models and static drawings, potentially restricting engagement beyond the immediate classroom setting.

As architectural education faces new socio-political and technological challenges, it is necessary to re-evaluate traditional methods not as outdated but as evolving frameworks that can be enhanced through contemporary innovations. Immersive technologies, such as VR and AR, complement traditional studio culture by enabling real-time spatial visualization, collaborative virtual environments, and interactive feedback mechanisms, thus extending the learning experience beyond physical boundaries. By integrating these tools, students can engage with their designs in more interactive and data-informed ways, deepening their understanding of spatial relationships and user experience while maintaining the core values of the studio model.

2.2.4 Schon's 'Knowledge in Action'

Donald Schon's theory of "knowledge in action" plays a significant role in traditional architectural pedagogy. In his work, Schon explains that certain types of knowledge are non-verbal and beyond mere theoretical understanding—they are applied in practice. According to Schon, knowledge in action refers to the implicit knowledge that professionals acquire through experience and practice, beyond what can be explicitly stated or taught in a classroom setting (Schön, 1983).

In his famous work *The Reflective Practitioner* (Schön, 1983), he categorizes knowledge acquisition into three methods: self-instruction, apprenticeship learning "on the line" in real-world contexts, and the practicum. However, he critiques self-instruction and traditional apprenticeships as being inefficient and potentially harmful in real-world applications due to their lack of comprehensive structure and oversight (Gruber & Mandl, 2001). The practicum, therefore, becomes the preferred mode of learning.

The practicum refers to a simulated environment that mimics real-world professional practice, allowing students to confront graduated design problems under the close supervision of a master practitioner or mentor. In this context, students engage in a series of exercises that increase in complexity, helping them to develop problem-solving skills in a "safe" environment before applying them in the real world (Schön, 1987). This mirrors the learning environment of the design studio, where students develop their ability to apply theoretical knowledge to practical design challenges, reinforcing the importance of reflection in action.

Reflection-in-action, as described by Schon, occurs when students try new approaches, assess their effectiveness, and adjust their strategies in real-time. The design studio, as the central pedagogical tool in architectural education, serves as the modern practicum where students engage in this reflective process (Schön, 1987). Under the guidance of tutors, students make design decisions, receive critiques, and learn to adjust their work through a process of iterative improvement.

Problem-solving is at the heart of this reflective practice, forming a continuous thread throughout the architectural design process. As students confront design challenges, they are encouraged to explore multiple solutions, experiment, and iterate. Traditionally, problem-solving in architectural education has relied on physical modeling, 2D drawings, and CAD software, each of which provides valuable but somewhat limited methods of spatial exploration.

In contemporary architectural education, this problem-solving process is undergoing a significant transformation with the introduction of immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR). Rather than replacing traditional approaches, these tools expand the ways in which students engage with design problems

by offering interactive, real-time simulations where they can test and refine ideas within an immersive digital environment (Whyte & Nikolić, 2018).

This shift represents more than just an incremental improvement; it introduces new dimensions to problem-solving by enabling students to:

- Directly inhabit and manipulate digital spaces, fostering deeper spatial understanding.
- Simulate real-world material properties and environmental conditions, allowing for more informed design decisions.
- Collaborate remotely in shared virtual environments, enhancing teamwork and interdisciplinary engagement.

Thus, rather than simply enhancing traditional methods, immersive technologies provide a paradigm shift in architectural problem-solving by allowing students to engage with complex design challenges in real-time, dynamic, and interactive ways. This redefinition of spatial and experiential design learning is what can be considered a revolution in architectural education—not in the sense of replacing existing practices, but in its ability to fundamentally extend and enrich the design exploration process.

2.2.5 Criticisms on ‘Reflective Practitioner’

While Donald Schon's *The Reflective Practitioner* has had a profound influence on architectural pedagogy, it has not been without its critics. For example, one such critic is Dutton (1991), who argued that Schon's model of reflection-in-action does not fully account for the complexities faced by practitioners in the real world. Dutton's criticism points to the gap between reflective practice in the relatively controlled environment of the design studio and the more chaotic, multidisciplinary nature of real-world architectural practice. The widespread endorsement of current design studio practice is

flawed, and moreover, Schon's ideas have thus far acted as a legitimising agent, with their dominance serving as a mere convenience that justifies the status quo (Till, 2005).

Critics argue that the complexities of contemporary architecture, such as construction, environment, materials, and regulations, are too vast for any one individual to master. The studio environment, which synthesizes all these factors, places significant pressure on students to integrate and manage knowledge from multiple disciplines (Dutton, 1991). However, it is arguably unrealistic to expect a single individual, particularly a student, to grasp and synthesize all of this information fully. In professional practice, architects typically work as part of teams, with specialists in areas such as structural engineering, environmental design, and materials science providing expertise that complements the architect's broader role (Lawson, 2006).

At the same time, others argue that the design studio can serve a more generalist function, allowing students to demonstrate a broad understanding of architectural design without necessarily delving into specialized knowledge. In this approach, the goal is not for students to develop fully resolved designs, but rather to explore conceptual approaches and develop a holistic understanding of the design process. Some educators argue that allowing students to specialize in particular areas, such as environmental design, may better prepare them for the increasingly specialized nature of contemporary practice (Lawson, 2006). However, this raises a broader question about how architectural education should balance specialization with foundational, conceptual learning across different stages of study.

Architectural education typically extends over four to seven years, incorporating undergraduate study, postgraduate training, and professional practice requirements. The challenge is not necessarily a binary choice between generalist and specialist learning, but rather how the emphasis shifts at different stages. In the early years of study,

the curriculum typically prioritizes broad conceptual learning, providing students with a strong foundation in design principles, history, and technical knowledge. As students progress, greater opportunities for specialization emerge, often through electives, research projects, or postgraduate study, allowing them to develop expertise in specific areas while maintaining a holistic understanding of architectural practice (Salama & Wilkinson, 2007).

This evolving balance reflects the realities of contemporary practice, where architects are expected to possess both a broad knowledge base and the capacity to develop specialist expertise in response to professional demands. Rather than viewing specialization and conceptual learning as opposing forces, the real challenge is structuring architectural education in a way that provides flexibility for students to explore diverse paths while ensuring a strong core competency in design thinking and problem-solving. This study examines how emerging technologies, such as immersive environments and computational design tools, can support both broad-based learning and specialized skill development, ensuring that graduates are equipped for the complexities of modern architectural practice.

The relationship between conceptual exploration and the development of a resolved architectural scheme represents a continuum rather than a strict binary opposition. Some architectural programs place greater emphasis on conceptual design methodologies, fostering innovation, experimentation, and speculative thinking, while others prioritize technically resolved, buildable solutions that align closely with professional practice expectations (Salama & Wilkinson, 2007). However, most programs aim to integrate both aspects, recognizing that successful architectural education must cultivate creative, reflective designers who also possess the technical and practical skills required for real-world application (Schön, 1983).

The role of the design studio as a space for reflective practice and iterative learning continues to evolve in response to technological advancements and environmental imperatives. Rather than presenting a forced re-evaluation, these shifts reflect the natural progression of architectural education, where traditional pedagogies are continuously reassessed and expanded to incorporate digital tools, sustainability-driven approaches, and interdisciplinary collaboration (Drach & Boud, 2021).

As the profession continues to evolve, the challenge for educators is not to choose between competing priorities, but to establish a pedagogical framework that embraces both conceptual freedom and technical proficiency, ensuring that graduates are prepared for the diverse expectations of contemporary practice. This study explores how immersive technologies and computational design tools can help balance these priorities by fostering an educational model that is both speculative and practice-oriented.

Another argument is that the design studio can serve a generalist role, where students are not expected to become experts in every specialized area but are encouraged to develop a broad understanding of design principles. This approach allows students to engage with complex projects holistically, integrating knowledge from multiple disciplines without the expectation that they will resolve every aspect in detail.

However, architectural education also recognizes the growing importance of specialization in areas such as sustainability, digital fabrication, and structural systems (Lawson, 2006). While some programs provide generalist training in the early years, others incorporate specialized pathways or elective tracks that enable students to deepen their expertise in specific areas.

Rather than presenting a strict binary choice, the challenge for educators is to determine how to balance foundational design education with opportunities for specialization. The

evolving demands of the profession suggest that both breadth and depth are valuable—architects must possess a broad conceptual understanding while also having the ability to develop targeted expertise when needed. This study explores how emerging technologies, such as immersive environments and computational tools, can support both generalist and specialist learning, providing students with adaptive skill sets suited to contemporary architectural practice.

Further complicating matters is the integration of new technologies into the curriculum. Immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) offer opportunities for students to engage with design problems in ways that were previously unimaginable. These tools allow for more interactive, real-time exploration of architectural designs, offering students a deeper understanding of spatial relationships, user experience, and materiality (Whyte & Nikolić, 2018). While these technologies hold great promise, they also introduce new questions about how to incorporate them into an already dense curriculum and how to train educators to effectively use these tools in the design studio.

2.2.6 The Anchor of Architectural Education

The design studio in essence represents a structure and system that positions the learner at the center of the process, facilitating and encouraging the development of complex and sophisticated learning (Masdéu & Fuses, 2017). The intention is to bring together a broad range of disciplines—environmental, structural, technological, historical, etc.—integrating them into the learning process. In this regard, the design studio, in concept, serves as a catalyst to achieve the notion of a "total studio" (Levy, 1980, p. 25). According to Levy, the "total studio" assumes that all aspects of architectural education—design teaching and related fields—are conducted within the context of the studio. This presents significant challenges, particularly related to the skillsets of the masters overseeing the

design process. These individuals are expected to possess a broad range of expertise to guide students through diverse disciplines, yet this is not always realistic in practice (Levy, 1980, p. 27).

However, according to contemporary research (Park & Lee, 2022; Oz Mehmet & Alakavuk, 2016; Utaberta et al., 2013), the design studio often fails to function in the intended manner. At the 49th International Conference of the Architectural Science Association (Crawford & Stephan, 2015), multiple researchers highlighted several deficiencies in the current design studio model. These issues arise from a lack of understanding of the behaviors, views, and actions that shape studio learning and the widespread failure of academics to engage with the fundamental pedagogic principles that underpin studio teaching (Crawford & Stephan, 2015, p. 78).

As noted by Donlyn Lyndon in 1978, "The trouble with architects is that when they think about architectural education, all they can do is think about what their own education was like" (Lyndon, 1978, p. 12). This quote captures the tendency for architectural education to perpetuate traditional methods, as many educators base their teaching approaches on their own past experiences rather than adapting to contemporary demands.

However, the presence of practitioner tutors—architects who actively work in the field while teaching—complicates this perspective. On one hand, practitioners may reinforce existing industry norms, bringing real-world constraints, professional expectations, and established workflows into the studio. On the other hand, they can also serve as agents of change, introducing students to cutting-edge technologies, emerging sustainability practices, and interdisciplinary collaborations that may not yet be widely embedded in academic curricula.

In many cases, practitioner tutors challenge entrenched pedagogical models by providing firsthand insight into evolving industry trends and pushing for more practice-oriented learning experiences (Drach & Boud, 2021). Their presence helps disrupt the idea that architectural education is purely cyclical, instead positioning it as a continuously evolving discipline shaped by both academic discourse and professional practice.

While architectural education has historically leaned on traditional methods, the engagement of practitioner tutors, industry partnerships, and technological advancements ensures that it does not remain static. This study further explores how technological interventions, such as immersive environments, can act as another catalyst for bridging the gap between traditional education and contemporary architectural challenges.

There are two primary challenges related to the diversification of architectural education:

A diverse range of students is now choosing to study architecture, each bringing their own unique perspectives, experiences, and expectations. This diversity can enhance creativity and innovation but also presents challenges in creating a curriculum that accommodates different learning styles, backgrounds, and needs. For instance, students from non-traditional educational backgrounds may require different levels of support and engagement, which puts pressure on educators to develop inclusive teaching strategies (Stevens, 1998, p. 45).

The diversification of curriculum content, particularly with the growing emphasis on environmental design, digital tools, and sustainability, has further complicated the structure of architectural education. While environmental considerations have long been a component of design pedagogy, the increasing urgency of climate change, energy efficiency, and sustainable construction practices has required a more structured and

integrated approach to teaching sustainability within the curriculum (Salama & Wilkinson, 2007).

For example, incorporating sustainability into the design studio requires not only theoretical understanding but also practical application, such as real-time energy modeling, passive design strategies, and lifecycle analysis of materials. These aspects demand technical proficiency and interdisciplinary collaboration, making them difficult to fully explore within the confines of a single course.

This ongoing expansion of specialized knowledge creates a challenge in maintaining the holistic approach that architectural education seeks to achieve. As new methodologies, certifications (e.g., LEED, BREEAM), and digital sustainability tools continue to evolve, educators must balance broad conceptual learning with the need for specialized technical training, ensuring that students develop both foundational design competencies and the ability to engage with complex environmental imperatives in practice.

As Kerry Francis (2015) notes, despite nearly a century of professional degree programs in architecture worldwide, "there remains an ever-present tension between the constituent elements of the discipline" (Francis, 2015, p. 89). This tension highlights the complexity of integrating new and old pedagogic approaches to create a cohesive educational experience for the modern architect, particularly within the evolving context of the design studio.

2.2.7 'Hard' and 'Soft' Learning in Architectural Education

The clash between "hard" and "soft" learning, as defined by Donald Schön, has been a frequent subject of contemporary research and discussions about the shortcomings of architectural education. "Hard" learning refers to analytical, logical, and structured education, while "soft" learning focuses on creative, conceptual, and intuitive education.

This distinction has been used to frame debates over whether architectural education should emphasize technical proficiency or conceptual design freedom.

According to Albrecht (1984, p. 45), modern architectural education often suffers from a disconnect between these two forms of learning, stating that:

"Students receive a half-brained education that undermines their overall intellectual potential by overemphasizing the strengths of one hemisphere while neglecting the other."

Albrecht argues that design studio education should encourage both creativity and rigor, fusing different cognitive processes to produce well-rounded architects. He warns that focusing solely on creativity without developing critical analytical skills can be detrimental to a student's overall development.

However, while this framework has been influential, it has also been critiqued. Cognitive neuroscience research has challenged the strict left-brain/right-brain dichotomy, arguing that creative and analytical thinking are not isolated in separate hemispheres but instead rely on interconnected neural networks throughout the brain (Nielsen et al., 2013). Furthermore, educational psychology studies suggest that effective architectural education does not require an artificial balance between two hemispheres but rather an integrated approach that fosters both analytical and creative competencies (Sawyer, 2011).

Despite these critiques, the broader argument remains relevant—architectural education must find ways to bridge technical learning and conceptual exploration, ensuring that students develop both critical thinking and creative problem-solving abilities. This study explores how immersive technologies and digital design tools can

support this balance, providing an environment where students can experiment, analyze, and iterate in a dynamic and integrated way.

Albrecht's argument aligns with Levy's "total studio" concept, where all aspects of architectural education—design teaching and related fields—are integrated within the studio environment. The design studio should provide a balanced space where students are encouraged to be creative while also being exposed to the rigors of structural, environmental, and technical considerations. This integrated approach ensures that students develop both the soft, creative skills and the hard, technical expertise necessary to succeed in the architectural profession (Levy, 1980, p. 26).

Schön's theories suggest that the "soft" elements of education, such as creativity and reflective practice, are crucial to architectural training, but they cannot exist in isolation from the "hard" components like structural engineering, environmental systems, and material science (Schön, 1983, p. 78). Educators face the challenge of creating a balanced curriculum that ensures students can think critically and creatively while also mastering the technical knowledge required for professional practice.

Furthermore, there are two key challenges that architectural educators face today:

A more diverse range of students is choosing to study architecture, bringing with them different cultural backgrounds, perspectives, and educational experiences. While this diversity enhances creativity and innovation, it also presents challenges in creating a curriculum that caters to various learning styles and educational expectations. Students from non-traditional backgrounds may require different forms of support, and educators must develop inclusive teaching strategies to accommodate this diversity (Stevens, 1998, p. 52).

The diversification of the curriculum itself, as it now incorporates advanced fields like sustainability, digital design, and immersive technologies, adds complexity to architectural education. For instance, introducing digital tools like Virtual Reality (VR) and Augmented Reality (AR) into the design studio helps students engage with spatial design in innovative ways, but it also requires educators to adapt their teaching methods to effectively integrate these technologies (Whyte & Nikolić, 2018).

The tension between “hard” and “soft” learning mirrors the broader challenges facing architectural education. Educators must not only prepare students to engage in conceptual, creative thinking but also provide them with the technical skills needed to succeed in an increasingly complex, globalized profession. Balancing these two elements is essential for ensuring that students graduate with both the creative flexibility and technical expertise required in today’s architectural landscape.

2.2.8 Legacy of ‘Teachers’ of Architecture

As Donlyn Lyndon pointed out, the views of ‘teachers’ of architecture, both academic and practitioner, are often a product of their own learning experiences. This observation is echoed in Stevens’ (1998) analysis of the relationship between the academic-dominated lecture forum and the practitioner-dominated studio forum, and later discussed by Rutherford and Wilson (2006) in their work on environmental awareness and creativity in integrated environmental design teaching. The influence of these historical learning experiences often shapes the approach that teachers take in the studio, leading to the replication of traditional methods that may not fully address the needs of today’s diverse student population (Park, 2014).

The diversification of the student population culturally, ethnically, and economically demands that educators not only acknowledge these differences but also capitalize on the opportunity to enrich the learning experience. Today, cultural diversity is reflected in

the work produced by students, with varied cultural backgrounds contributing unique perspectives to the design process (Chick, 2013). However, economic challenges are also becoming a major factor. Many students now work part- or even full-time jobs to fund their studies, leading to issues with attendance and participation in studio work (Vinson, 2019). Furthermore, there is increased pressure to diversify the student population through access programs that target ethnic minorities and underrepresented groups. These programs, designed to widen participation, sometimes involve accepting students with lower entrance requirements due to circumstances beyond their control. As a result, educators face the challenge of teaching a highly diverse group of students with a broad range of abilities, which requires the development of inclusive teaching strategies to support all learners (Stevens, 1998; Chick, 2013).

In independent learning, educators must also be aware of the different learning styles that students bring with them. These learning styles may be less visible than cultural or economic differences, but they are equally important in ensuring that all students can engage meaningfully with the material. Failure to recognize these differences may lead to a disengaged student body and a less effective learning environment overall (Kolb, 1984).

The hierarchies that emerge in the social relations within the studio can create asymmetries between staff and students, resulting in a power dynamic that must be carefully managed by the staff. If educators fail to understand this dynamic, it can lead to what Schön referred to as a 'counter learner,' where students feel alienated and disengaged from the learning process rather than participating in the open dialogue and discourse that the studio model is intended to foster (Schön, 1983). The 'counter learner' is often a student who feels excluded or marginalized by the teacher-student hierarchy, which undermines their ability to engage with the learning environment.

Behaviours in the studio play a crucial role in communicating the cultural values and collective 'persona' of the profession. For example, a lack of openness to criticism can stifle student creativity, while encouraging collaborative problem-solving fosters an environment of innovation and shared learning (Sauer, 2011). Another example is how educators respond to student mistakes: an environment where mistakes are seen as learning opportunities can empower students, while an overly critical approach can discourage them from taking creative risks (Sauer, 2011). These behaviours not only shape the dynamics of the studio but also reflect the professional culture that students will encounter after graduation.

2.2.9 Preserving Traditional Ideologies of Reflection

In relating Goatly's *Developing Skills in Reflection* (1999) to the findings of the AIAS Studio Culture Task Force (2002), it becomes evident that studio practices are inadvertently hindering the development of core reflective skills. The design review process, which is traditionally perceived as a negative, even brutal experience, also plays a critical role in the reflective process. This aspect of reflection can be linked to Donald Schön's concept of *Reflection-on-Action*, where professionals critically evaluate their past actions to improve future practices (Schön, 1983).

Although many schools have revisited traditional practices related to design reviews in an effort to make them less adversarial and reduce conflicts in agenda, others continue to defend their criticality, viewing the process as a rite of passage to professional competence (Jones, 1996). Schön's reflection-on-action process helps illuminate the value of this critical evaluation, where students are expected to reflect upon their work post-review and use this reflection to improve their design skills.

However, in creating the independent learner, self-confidence and motivation are fundamental components. Schön's *Reflection-in-Action* concept also emphasizes that

students should not only reflect after the fact but engage in real-time reflection during the design process itself (Schön, 1983). This approach fosters immediate problem-solving and self-awareness, where students can make adjustments based on immediate feedback or their own reflections as they work.

Therefore, more must be done to develop structured pedagogic processes that build reflective skills based on personal confidence. This includes fostering an environment that supports both reflection-in-action, which happens in the moment, and reflection-on-action, which occurs after completing a task (Akimova et al., 2021). By cultivating reflective practices that build self-confidence and encourage immediate problem-solving, architectural education can create more resilient and adaptable students, better equipped for professional practice.

2.2.10 Design Studio as a 'Forum'

The role of the studio setting as a learning medium, community forum, and social agent is widely documented, particularly aligning with Nicol and Pilling's (2000) five principles for effective learning. These five principles include active learning, collaborative learning, feedback and assessment, integration of knowledge, and reflection. These principles emphasize that the design studio should provide a space where students actively engage with their work, collaborate with peers, receive continuous feedback, integrate knowledge from diverse fields, and engage in critical reflection on their design processes (Nicol & Pilling, 2000; Schön, 1983).

However, the way that studio is inhabited and engaged with continues to evolve, particularly given the economic pressures forcing an increasing number of students to maintain part-time employment in order to support their studies (Smith & Smith, 2012). This economic reality often results in students spending less time physically present in the studio, which challenges the traditional model of the studio as a place of continuous

immersion in design work (Stevens, 2015). As students balance work and study, relationships within the studio, both with peers and tutors, are becoming more fragmented, leading to a decrease in informal peer learning and spontaneous collaboration, which have traditionally been key components of the studio experience (Belluigi, 2013).

Advances in IT have also contributed to the rise of a more mobile, or peripatetic, student body. While traditionally the term refers to physical movement, in this context it describes how students are no longer required to be physically present in the studio to engage with their work. With the increased use of digital tools, online collaboration platforms, and virtual communication, students are able to work remotely while still participating in design projects and critiques (McClean, 2009). This shift has altered the studio's role as a central learning environment, as students can now engage with their work, tutors, and peers from remote locations. However, the decreased physical presence in the studio can weaken the immersive and collaborative nature of the traditional studio model (Vinson, 2019).

These changes present challenges to how the studio functions as a forum for learning. The physical absence of students from the studio reduces opportunities for the spontaneous collaboration and informal peer learning that have traditionally been central to the studio model (Smith & Smith, 2012). While technology has enabled greater flexibility, it has also introduced challenges in maintaining the collaborative, immersive atmosphere that is critical to the studio experience (McClean, 2009).

2.2.11 Satellite Modules

The separation and isolated treatment of the lecture forum and studio results in a disjointed acquisition of knowledge and hinders holistic design thinking (Ozmehmet & Alakavuk, 2016; Ling, 2021). In architectural education, there is often a disconnect

between the acquisition of knowledge in lecture-based settings and its application in the design studio, leading to fragmented learning experiences (Park, 2014). This approach, often referred to as satellite teaching, emphasizes the acquisition of disciplinary knowledge in isolation, rather than as an integrated whole. The danger here lies in separating acquisition from application, which undermines the ability of students to synthesize and apply the various fields of knowledge to their designs (Levy, 1980).

While independent learning has its benefits and strengths, these are seldom fully realized when learners cannot holistically integrate and apply all the skills, knowledge, and theoretical perspectives they acquire into their designs (Crowther, 2013). Satellite teaching, where students receive knowledge in isolated modules, makes it difficult to foster the kind of integration necessary for architectural practice (Soliman, 2017). Warburton (2003) emphasizes the importance of anchoring ideas in a cooperative and active learning environment, where learning methods, delivery, and assessment are fundamentally questioned to ensure a holistic understanding.

Multidisciplinary has necessitated the use of satellite teaching, as architecture now involves various fields—art, psychology, engineering, technology, and science—requiring multiple experts to deliver specialized knowledge (Stevens, 2015). However, the studio should be the forum for integrating this knowledge. The studio must serve as the space where acquisition and application of knowledge are fused (Levy, 1980). Levy (1980) emphasizes that if the acquisition of knowledge is separated from its application, then the cyclical relationship between these two elements must be maintained and reinforced in the architectural curriculum.

As the literature suggests, architecture continues to grow rapidly in content and complexity. This necessitates periodic updates and the integration of new teaching methods to reflect the evolving demands of the field (Crowther, 2013; Stevens, 2015). The

design studio environment remains essential, as it is the place where multidisciplinary knowledge comes together, where theoretical knowledge from the lecture forum is applied in a holistic manner (Park, 2014). However, many of the issues in both traditional and contemporary pedagogy stem from the inefficient integration of design elements and technology into the studio environment (Soliman, 2017). Satellite teaching can create friction in this holistic system by separating the different aspects of architectural learning (Ling, 2021).

The review of literature suggests that there is a need for integrated and holistic strategies to foster independent learning, encompassing the student body, academic staff, and the learning environment (Stevens, 2015). The focus should be on bridging the gap between acquisition and application, ensuring that students can integrate the knowledge gained from various sources into their studio work in a meaningful way (Crowther, 2013). This integration must occur early in the learning process to create a more cohesive design solution.

Furthermore, while this section discusses the challenges posed by satellite teaching, new technologies, such as VR and AR, present opportunities for integration into the studio environment (Whyte & Nikolić, 2018). These tools can facilitate better communication of design ideas and provide students with interactive platforms where theoretical knowledge can be immediately applied in design exercises. By incorporating such technologies, the boundaries between acquisition and application can be blurred, fostering a more fluid and interactive studio experience (Whyte & Nikolić, 2018).

2.2.12 The Total Studio Theory

Levy's Total Studio theory is a key framework within traditional architectural pedagogy. As described by Levy (1980), "the Total Studio is an ideal pedagogical construct, representing the holistic approach to architectural education to which a great proportion

of architectural educators and programs aspire, but which few have even partially achieved” (Levy, 1980, p.29). This academic model attempts to create a fully integrated learning environment where all aspects of architectural knowledge—from design to technical subjects—are merged. However, it is often difficult to achieve, leading to the use of satellite teaching models that separate acquisition and application of knowledge (Levy, 1980). This separation can hinder the student's ability to relate technical knowledge to design work.

In his work, Levy discusses the separation of the architectural curriculum into studio and non-studio components in traditional pedagogy. The proposal for a holistic teaching approach stems from a need to enhance the learner experience and value, but the challenges of achieving a Total Studio model are significant (Levy, 1980). Multidisciplinary teaching, especially in complex fields like architecture, often necessitates satellite teaching because it requires specialized knowledge from various experts in fields such as environmental engineering, structural mechanics, and materials science. This model supports the argument that a holistic approach is ideal, but it also highlights the difficulties of integrating specialized knowledge into the studio setting (Gelernter, 1988).

The separation of technical subjects from design leads to a lack of engagement and relatability for the student. As architectural education has become more complex and multidisciplinary, it is no longer feasible for a single master or teacher to possess all the specialized knowledge required in practice. This shift away from the traditional master-apprentice model reflects the need for students to acquire knowledge from a wide range of experts, typically delivered through satellite modules in lectures. The studio, therefore,

returns to the historical model of teaching where knowledge is distributed across different areas of expertise, yet integrated through design practice (Schön, 1983).

Levy (1980) outlines the main challenges of the holistic studio approach: increased demand for resources, including time, faculty expertise, and student commitment. He also raises the issue that the idea of one teacher—or even a team of teachers—being able to manage all aspects of architectural education is unrealistic. In practice, architectural projects are delivered by teams, where specialists in areas such as environmental engineering, M&E (Mechanical and Electrical), and structural design collaborate. It is therefore not reasonable to expect students to assimilate all this specialized knowledge into their designs, especially within a studio environment (Levy, 1980, p. 30).

In modern architectural education, the role of the studio tutor is less about mastering all the specialized knowledge and more about teaching students how to communicate effectively with experts in other fields. As an analogy, if studio tutors speak "French," and specialists in other fields speak "German" or "Greek," then the role of the student is to understand the basic syntax of these languages so they can engage with specialists in areas like environmental or structural engineering. The argument here is that while students may not be able to master each area in detail, they should develop a working understanding that allows them to engage effectively with interdisciplinary teams (Rutherford & Wilson, 2006). Unfortunately, many studio tutors primarily engage with a specific "language" of architectural education, often rooted in their own area of expertise. For some, this language is aesthetics and spatial composition, while for others, it may be technical detailing, structural systems, sustainability, or digital fabrication. Similarly, faculty members teaching in satellite modules, such as history, environmental design, or computational design, often approach architecture through discipline-specific

frameworks, which may not always align seamlessly with the studio's holistic, integrative approach.

While specialization is necessary, it can create communication gaps between different areas of architectural education. If tutors focus primarily on form-driven aesthetics, they may underemphasize the technical feasibility and materiality of a design. Conversely, a technically focused tutor may prioritize structural logic and performance metrics over conceptual exploration and spatial experience. This fragmentation of knowledge can make it difficult for students to synthesize multiple perspectives into a cohesive architectural approach.

Bridging these gaps requires pedagogical strategies that encourage interdisciplinary collaboration, ensuring that students can navigate between theoretical discourse, design innovation, and technical problem-solving. This study explores how immersive technologies can facilitate this integration, allowing students to engage with design problems holistically by visualizing spatial relationships, testing environmental performance, and refining structural solutions in an interactive, real-time environment.

The Total Studio theory presents both a compelling vision and significant challenges. On the one hand, it offers a holistic, integrated approach to architectural education. On the other hand, it is difficult to implement in practice due to the complexities of architectural projects and the need for specialized knowledge. This research explores whether immersive technologies such as VR and AR can help bridge the gap between acquisition and application, supporting the integration of different fields of knowledge in the studio environment (Whyte & Nikolić, 2018).

Furthermore, the rising trend of short-term apprenticeship programs in undergraduate curricula, endorsed by institutions like RIBA and ARB, supports the need for hands-on learning experiences that bridge studio education and professional practice. These

programs, typically lasting between 6 to 12 months, are often embedded within architecture degrees as structured work placements or alternative routes to qualification, such as the Level 6 and Level 7 Architectural Apprenticeships in the UK (RIBA, 2020).

These apprenticeship models are gaining traction as they address financial pressures faced by students, allowing them to earn while they learn and gain real-world industry exposure. However, integrating apprenticeships within traditional design studio education presents logistical challenges, as balancing on-site practical experience with academic learning can disrupt the continuity of studio-based pedagogy.

Emerging technologies such as VR and AR may offer solutions, providing students with virtual site visits, real-time collaborative workspaces, and digital simulations of construction environments, ensuring that experiential learning can be integrated without compromising the pedagogical framework of studio education. By combining physical and virtual learning experiences, these new approaches could provide greater flexibility in architectural training while preserving the depth of reflective practice central to studio-based education.

2.2.13 Fantasy Design Studio

According to Bryan Lawson, one obstacle to traditional architectural pedagogy has been the dogmatic approach to the teaching of history, which has often been treated as deserving of academic study while making little connection with the present (Lawson, 1990). This reflects a broader issue in humanities teaching, where the study of history can become detached from contemporary practice, leaving students with theoretical knowledge that they find difficult to apply in real-world scenarios. In contemporary education, this detachment has begun to change, with a more flexible approach that

allows students to appreciate historical work for its own sake while also using it to inform contemporary design practice.

In Bryan Lawson's *How Designers Think*, he argues that the design studio should focus on "learning by doing", where students are presented with a series of design problems to solve (Lawson, 1980, p. 35). The goal is for students to learn the design process through practical application rather than by purely studying or analysing it. This applied learning approach emphasizes the importance of process over the end result, contrasting with traditional pedagogy, which often focused too heavily on the final product. The shift in focus aligns with contemporary efforts to integrate real-world challenges into studio work, including issues such as client demands, budgets, and time constraints.

However, Lawson also points out that the difficulty of integrating these realistic problems into the design studio creates obstacles for fully achieving the studio's intended potential. The lack of connection to realism in the design studio is partly due to student and tutor expectations, with students often struggling to adopt a process that engages all the stakeholders involved in real-world design (Lawson, 1980, p. 60). Instead, students tend to develop processes aimed primarily at satisfying themselves or their tutors. This issue highlights one of the dangers of the master-apprentice model: students may be attracted to tutors who share their own biases, leading to narrow approaches that either overly emphasize personal expression or rigid pragmatism.

In traditional pedagogy, this resulted in what Lawson describes as the "fantasy studio," where design projects often lack relevance and connection to real-world issues. This disconnection from reality can distort the balance of skills and values that students acquire, reducing the overall quality of the learning experience (Lawson, 1980, p. 80). This phenomenon can manifest in both directions—either in overly fantastical, self-reflective projects or in overly pragmatic ones that leave little room for creative design exploration.

In both cases, students are not receiving the balanced education necessary to succeed in a professional setting, where they must navigate both creative and practical constraints.

In relation to this PhD research, the relevance of these concerns is particularly evident when considering how biases from tutors can impact the integration of new technologies such as CAAD or immersive technologies like VR and AR. For instance, a technophobic tutor might see no relevance in these technologies, leading students to form biased opinions based on limited exposure to their potential applications in design. At the formative stages of their education, students are highly susceptible to the preferences and biases of their tutors, which can shape their attitudes towards technology and innovation (Rutherford & Wilson, 2006).

This underscores the importance of providing a more balanced and integrated approach to studio teaching, one that allows students to explore both creative design and practical constraints through applied learning and new technologies. By integrating tools like VR and AR, it may be possible to overcome some of the challenges presented by the fantasy studio model, creating a more realistic and immersive learning environment where students can engage with design problems in a holistic manner (Whyte & Nikolić, 2018).

2.3 Contemporary Period

The contemporary period of architectural education is marked by the integration of digital technologies and a focus on interdisciplinary learning. The rise of Computer-Aided Design (CAD) and Computer-Aided Architectural Design (CAAD) has transformed the studio environment, enabling more complex and precise design work (Andia, 2002). Additionally, the pressures of

increasing student numbers and declining resources have necessitated innovative approaches to teaching.

The incorporation of Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) technologies extends these innovations by offering highly immersive and interactive design experiences that enhance creativity, spatial cognition, and real-time collaboration. VR enables students to inhabit their designs at full scale, allowing them to perceive spatial relationships, proportions, and lighting conditions in ways that traditional 2D drawings and physical models cannot achieve. AR, by overlaying digital elements onto real-world settings, enables students to visualize designs in context, interact with augmented environments, and refine spatial concepts dynamically. MR merges both physical and digital design workflows, enabling real-time collaboration between students and tutors across different locations while maintaining a tactile connection to physical models (Spiridonidis & Voyatzaki, 2007; Pearson, 2020).

Beyond visualization, these technologies directly support creativity by allowing iterative and experimental design processes. Students can explore multiple design alternatives without the time constraints or material limitations imposed by physical models. Additionally, the ability to test spatial, structural, and user-experience scenarios in real-time fosters a deeper engagement with design thinking. This interactive approach encourages risk-taking and innovation, key components of architectural creativity.

Another crucial advantage is their ability to facilitate the integration of specialized knowledge into the studio environment. Traditional architectural education often struggles with incorporating structural engineering, environmental analysis, and human behavior modeling into the design process due to limited visualization tools. VR, AR, and MR overcome this by allowing real-time simulations of environmental factors, structural stress tests, and human movement analysis within immersive environments. This integration enhances students' understanding of how

buildings interact with users and their surroundings, ensuring a more informed and holistic design approach.

By addressing these challenges, VR, AR, and MR hold the potential to bring about significant innovation in architectural education. They shift the studio from a static and isolated environment to a dynamic, collaborative, and interdisciplinary learning space where students can engage with complex spatial and theoretical concepts more intuitively. The application of these technologies represents a transformative step in architectural pedagogy, aligning education more closely with professional practice and ensuring that students graduate with the digital competencies required for the evolving architectural profession.

2.3.1 Declining Resources in Contemporary Architectural Pedagogy

"Nowhere in Western Europe have the changes in the nature of the university as an institution accelerated so rapidly as in Britain, where the pace and profundity of reform have perhaps been exaggerated because of its relative lateness in making the move from elite to mass higher education" (Smith & Webster, 1997, p. 15). Although this statement was made to reflect on higher education in general and over two decades ago, sadly, many aspects of this situation are still echoed in today's education system.

The continuous and dramatic rise in higher education student numbers within the UK has had a significant impact on changes to the system. Statistical data from the 1960s to the 2000s shows a fourfold increase in student numbers (Blanden & Machin, 2004), and between the 2000s and 2016, this figure almost doubled according to the Office for National Statistics. As expected, the strain caused by this increase in student numbers within UK higher education has also directly impacted traditional architectural pedagogy.

The increased demand has led to a reformation in the architectural educational approach, accompanied by limitations in budget and resources (Jenkins, Forsyth, & Smith, 2005). Budget cuts, reduced studio space, and larger class sizes have made it

increasingly difficult for educators to provide the same level of individual attention and support that has traditionally been a cornerstone of architectural education (Smith & Webster, 1997). As a result, the design studio experience has had to adapt, with many schools turning to digital tools and online platforms to supplement reduced physical resources (Blanden & Machin, 2004).

2.3.2 Quality of Facilities and Rise of Student Numbers

The aforementioned reductions in resources have significantly impacted the quality of learning facilities, academic salary structures, and increased financial hardship for students (Smith & Webster, 1997). These issues continue to pose serious challenges in today's educational landscape, affecting both students and faculty members. In architectural education, where access to high-quality facilities is crucial, any reduction in resources can severely hinder the delivery of the program. For example, limitations in studio space, workshop facilities, and digital tools directly affect students' ability to engage fully with the hands-on, experiential learning that is central to architectural pedagogy (RIBA, 2019). Without adequate resources, students may struggle to complete design projects to a high standard, which in turn diminishes their learning experience (Peterson, 1971).

The quality of facilities directly influences the overall effectiveness of the program, as architecture requires specialized spaces and tools for activities such as model-making, drawing, and digital design. Reduced access to these facilities not only limits students' practical experience but also hampers their ability to experiment and innovate, which are essential components of creative architectural education (Jenkins, Forsyth, & Smith, 2005).

In addition to the rise in student numbers, another factor that played a key role in the reformation of the education system, particularly in architecture, is the government-

backed initiative known as the Widening Participation agenda. This initiative has its origins in the Robbins Report of 1963, which recommended the expansion of higher education to include more students from diverse ethnic, socio-economic, and educational backgrounds (Shaw et al., 2007). While this agenda introduced a wealth of new ideas and perspectives, it also created significant challenges for educators in maintaining academic standards and meeting the diverse needs of an increasingly varied student body. The increase in student diversity brought about new challenges, such as the need for more personalized teaching approaches, additional academic support, and resources to address the different educational backgrounds of students (Baker & Brown, 2015).

In relation to this research, these challenges are relevant when considering the role of new technologies, such as Virtual Reality (VR) and Augmented Reality (AR), in addressing some of the gaps caused by resource limitations. Immersive technologies offer the potential to create virtual studio environments where students can engage in design exercises without the same physical limitations posed by reduced access to traditional facilities (Whyte & Nikolić, 2018). For example, students can use VR to simulate real-world environments, allowing for design exploration that might otherwise be constrained by a lack of physical space or tools (Foster, 2018). These technologies may help bridge the gap created by declining resources, offering new ways for students to engage with architectural design in an interactive and immersive manner.

2.3.3 Stress in Widening Participation

The movement of inclusiveness, driven by the Widening Participation agenda, has had a notable impact on architectural education. The increase in diversity among students—who bring different perceptions, preconceptions, expectations, prior education, learning styles, and social and cultural backgrounds—has enriched the learning environment. As

previously mentioned, this diversity adds value to education by introducing new perspectives. However, it also creates significant challenges in terms of maintaining teaching efficiency and addressing the varied needs of an increasingly diverse student body (Stevens, 1998; Shaw et al., 2007).

One of the primary challenges is the varying levels of prior knowledge and technical proficiency among students. Some students may enter architectural education with strong backgrounds in mathematics, physics, or digital design tools such as Computer-Aided Design (CAD), while others may have had limited exposure to these subjects. This disparity requires educators to adapt their teaching strategies, often necessitating additional remedial instruction for some students while ensuring that more advanced students remain challenged (Jenkins et al., 2005).

Another significant issue is the difference in learning styles and educational expectations. Students from diverse cultural and academic backgrounds may have differing approaches to problem-solving, collaboration, and self-directed learning. Some may be accustomed to rote memorization and rigid assessment structures, while others thrive in open-ended, exploratory, and project-based learning environments. Balancing these differences within the same curriculum requires flexible teaching strategies that cater to multiple learning approaches while still meeting academic standards (Shaw et al., 2007).

Furthermore, language barriers and communication difficulties can arise in institutions with a high proportion of international students. Effective architectural education relies heavily on design communication, critique sessions, and peer discussions, making it essential for all students to engage confidently in verbal and visual articulation of ideas. Language proficiency differences can lead to disparities in participation and assessment

outcomes, requiring additional support structures such as specialized tutorials, peer mentoring, and scaffolding techniques (Stevens, 1998).

Additionally, the Widening Participation agenda places greater strain on teaching resources. As student numbers increase, faculty often experience higher teaching loads, reduced one-on-one mentoring time, and increased administrative responsibilities. Architectural education, which traditionally depends on studio-based learning and personalized tutor feedback, faces particular challenges in scaling these practices while maintaining high-quality education (Jenkins et al., 2005).

While inclusivity enhances the richness of architectural education, it also demands innovative pedagogical solutions to address these challenges. The integration of adaptive learning technologies, blended learning models, and peer-assisted learning strategies can help accommodate diverse student needs while preserving the quality of education. By acknowledging and proactively addressing these issues, educators can foster an environment that not only supports a wider range of students but also enhances the overall learning experience.

To further elaborate on the stress placed on education, funding for universities continues to come largely from public sources, creating a demand for accountability and transparency (Milliner, 2003). This has contributed to the emergence of a culture of "enhancement" aimed at driving up quality and standards in education (Milliner, 2003). However, this push for improvement comes at a time when the resources available for teaching are declining. As universities are expected to achieve more with less, this stress affects both the quality of education and the ability of institutions to provide personalized attention to students with varying backgrounds and needs (Baker & Brown, 2015).

A key focus within the enhancement agenda has been the First Year Experience. Substantial work has been done to understand and address complex issues related to

student engagement and retention during the first year, as this period is critical in shaping a student's overall educational journey (Krause et al., 2005). The first year is crucial because it is when students' assumptions and preconceptions about architecture are either reinforced or dispelled, and where their expectations and learning habits are established. Patterns of working, professional culture, and independent learning skills are also formed during this time, making it essential for institutions to carefully design the first-year curriculum to set the right tone for the remainder of a student's education (McInnis, 2001).

In relation to this PhD research, the challenges presented by widening participation have important implications for the integration of new teaching methods and technologies in architectural education. Since first-year students often struggle with basic tools such as CAD, immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) are more suitable for second-year students, who have developed foundational skills and are better equipped to engage with these technologies. By the second year, students have gained some experience in architectural design, allowing them to benefit more from interactive and immersive tools that can enhance their learning experience (Whyte & Nikolić, 2018). VR and AR offer the potential to create virtual studio environments where second-year students can explore architectural concepts in greater depth and with more autonomy (Foster, 2018).

The lessons learned from the First Year Experience can inform how immersive technologies are introduced into architectural education. While first-year students focus on building foundational skills, immersive technologies like VR and AR can be more effectively integrated in the second year, where students have the technical competency to engage with both creative and technical aspects of architecture (Sharma et al., 2017).

This approach can help maintain academic standards while also addressing the specific challenges posed by widening participation.

2.3.4 Importance of Student Expectation

Furthermore, the mentioned enhancement agenda has begun to change the nature of student expectations. This shift in expectations has been a popular subject of numerous studies conducted over the past three decades, for example, in research by Longden (2006). These studies examine complex and multifaceted issues related to student experience, providing a broad perspective on how expectations have evolved. One of the key findings is that with multiple external commitments, fewer students engage fully in university life, particularly compared to the generations that commonly teach them (James, 2001, p. 12). Understanding these generational differences in pedagogic experience is essential when delivering contemporary education.

Moreover, among some groups, higher education—particularly university education across all fields, not just architecture—is increasingly viewed as a commodity (Altbach, 2002, p. 19). In the UK, this perspective has been reinforced by regulations from the Competition and Markets Authority, which position students as consumers of educational services.

This commodification of education is further shaped by financial pressures on both students and universities. While tuition fees in England have remained capped at £9,250 since 2012, their real-term value has declined due to inflation, meaning that universities now receive approximately one-third less per student than they did in 2012 (IFS, 2022). Meanwhile, students continue to face rising living costs, higher student debt, and increasing scrutiny over the cost-value ratio of their education. These economic realities heighten student expectations, with many demanding clear and measurable returns on

their educational investment, including stronger career prospects, industry engagement, and cutting-edge learning resources (McCowan, 2018).

As tuition fees and funding structures evolve, institutions must demonstrate the value of their educational offerings. In architecture, this has led to greater emphasis on digital tools, practice-based learning, and innovative pedagogies such as immersive technologies, which provide students with experiential, industry-relevant training that aligns with their professional aspirations.

With these rising expectations, traditional methods and teaching styles may no longer be sufficient to meet the demands of today's students, especially in fields like architecture, where adaptability and constant evolution are key (Rolfe, 2002, p. 45). Students now expect more interactive, technologically integrated, and personalized learning experiences. For example, many students anticipate that digital tools like CAD, VR, and AR will be integrated into their education early on, as these technologies are becoming standard in professional practice (Whyte & Nikolić, 2018). Managing these expectations is a challenge for educators, who must find ways to balance innovative teaching methods with traditional pedagogic approaches.

In relation to this PhD research, the impact of student expectations is critical to understanding how new technologies like VR and AR can be effectively integrated into architectural pedagogy. Contemporary students expect learning experiences that are engaging, interactive, technologically relevant, and aligned with industry demands. These expectations can be categorized into four primary elements:

Immersive and Interactive Learning – Students seek experiential, hands-on engagement rather than passive, lecture-based instruction. Traditional methods such as 2D drawings and static CAD models often fail to provide a spatial and sensory understanding of architectural spaces. VR and AR address this gap by allowing students to interact with

and experience designs in a full-scale, immersive environment, reinforcing spatial cognition and real-world applicability.

Real-Time Iterative Design and Feedback – In fast-paced design education, students expect instantaneous feedback and iterative workflows. Physical models and traditional CAD-based methods often introduce delays in reviewing and refining designs. VR and AR enable real-time modifications and dynamic visualization, allowing students to test ideas, explore alternatives, and receive immediate tutor or peer feedback within an immersive setting.

Collaborative and Connected Learning – The shift toward globalized, interdisciplinary architectural education has heightened expectations for collaborative learning environments. Students are increasingly required to work in team-based design projects, often with peers and professionals across different locations. VR and AR facilitate real-time virtual collaboration, allowing multiple users to co-experience, analyze, and refine a design within a shared digital space, mimicking professional architectural workflows.

Industry-Relevant Digital Competency – With architecture increasingly relying on digital fabrication, computational design, and Building Information Modeling (BIM), students expect their education to prepare them for technological advancements in practice. VR and AR not only provide an intuitive bridge between conceptual design and digital modeling but also enhance familiarity with industry-standard visualization and simulation tools, ensuring that graduates possess skills relevant to contemporary practice.

As architectural education evolves to accommodate a diverse and technologically adept student body, immersive technologies offer an opportunity to directly align with and fulfill these evolving expectations. By providing experiential, iterative, collaborative, and industry-aligned learning experiences, VR and AR serve as critical pedagogical tools that

enhance students' design understanding, problem-solving abilities, and spatial cognition. Their integration into architectural curricula represents a transformative step in modernizing architectural education, bridging the gap between traditional studio models and future professional practice.

2.3.5 Response of the RIBA

Following the previously mentioned events and agendas, in 2003 the two UK professional and statutory bodies, the Royal Institute of British Architects (RIBA) and the Architects Registration Board (ARB), revised their set of criteria for regulating standards within accredited architecture schools. These criteria had existed prior to 2003 but were revised to better align with contemporary educational needs. Over the years, this framework has formed the foundation of contemporary architectural pedagogy, although it has received a fair share of criticism (Hawley, 2004).

Critics argue that these criteria impose unwelcome constraints on architectural education, forcing educators to focus only on teaching skills and knowledge that can be directly assessed and evidenced. This has led to concerns that the educational process has become too mechanistic, emphasizing measurable outcomes over creative exploration (Morrow, 2007). In a field like architecture, where creativity and exploration play a central role, an outcomes-driven system can feel restrictive due to the inherent unpredictability of creative processes (Heylighan, 2004). These criticisms, raised when the criteria were introduced, continue to resonate within contemporary architectural pedagogy.

However, it is important to note that while RIBA and ARB set the criteria for accreditation, they do not prescribe how educators should teach. Educators have considerable freedom in how they achieve the required learning outcomes, often relying on traditional methods that they themselves were taught (Milliner, 2003). Teaching methods are

generally left to the discretion of the institution, and while some educators pursue qualifications such as the PGCHE (Postgraduate Certificate in Higher Education), these programs typically do not impose specific teaching approaches. This flexibility allows for innovation in teaching methods but also perpetuates traditional approaches that may not fully meet the needs of today's diverse student body.

Despite the flexibility in teaching methods, one of the major criticisms of the RIBA and ARB framework is that it creates barriers to the introduction of newer, more innovative methods of teaching. These barriers are further compounded by ongoing financial constraints faced by architecture schools, as institutions struggle to balance rising student numbers with limited resources.

Governmental funding for higher education in the UK has declined in real terms, with university tuition fees frozen at £9,250 since 2012 while operational costs have increased, placing significant financial strain on institutions (IFS, 2022). In architecture schools, this has contributed to staffing shortages, increased workloads for educators, and fewer opportunities to experiment with new pedagogical models (RIBA, 2021). While exact figures on academic staff reductions in architectural education are not widely available, broader trends indicate that staff-to-student ratios have worsened in many UK universities, affecting the quality of studio-based learning and individual mentorship (UCU, 2023).

As a result, attempts to introduce major curriculum changes or adopt new teaching practices, such as immersive technologies, computational design, and interdisciplinary collaborations, are often met with institutional resistance due to budgetary limitations and workload concerns. Educators must navigate these constraints while striving to maintain high pedagogical standards, preparing students for an increasingly complex professional landscape.

In relation to this PhD research, the framework established by RIBA and ARB is significant because it shapes the structure of accredited architectural programs, which impacts how new technologies like Virtual Reality (VR) and Augmented Reality (AR) can be integrated. While the criteria themselves do not prevent the use of immersive technologies, the strain on resources and the tendency to rely on traditional methods can make it difficult to implement these new tools effectively. The challenge lies in finding ways to integrate these technologies into the curriculum in a way that satisfies the RIBA/ARB criteria while also addressing the needs of a diverse and growing student population.

2.3.6 Difficulty in Catering for Multiple Ambitions

It is important to recognize that while the majority of students pursuing architectural education aim for professional qualification, there are those whose ambitions lie outside of professional practice. This diversity in motivation is largely a consequence of the increasing number of students entering architectural programs, which in turn leads to a wider range of expectations and goals (McGonigal, 2005). As student motives become more varied, schools of architecture experience pressures that test long-standing conventions and orthodoxies. These conventions include the traditional emphasis on the design studio as the primary mode of learning, one-on-one tutor-student interaction, and the focus on professional preparation for practice (Hassanpour et al., 2013; Attoe & Mugerauer, 1991).

One source of friction arises from the reluctance of many tutors to abandon elements of traditional architectural pedagogy, particularly the design studio model. As Donald Schön's work in the 1980s highlighted, one-on-one teaching within the studio setting has long been viewed as an exemplar of effective design education, and this model has transitioned across to contemporary architectural pedagogy (Schön, 1983). However,

while these traditional methods were highly effective in the past, their transition to contemporary architectural education has not been without challenges. The pressures placed on education today—stemming from increased student numbers, reduced funding, and a changing professional landscape—have made it difficult for these methods to remain as effective as they once were.

These pressures include low funding levels, reduced space standards, and the increasing cost of delivering architectural education, which have strained the system and limited the resources available for one-on-one teaching and hands-on learning experiences (Rooney, 2005). Performance measures, which emphasize quantifiable outcomes over creative exploration, are also seen by some educators as contrary to maintaining desirable professional standards in design education (White, 2000). As a result, traditional teaching methods that relied heavily on personalized instruction and small class sizes are becoming less viable, leading to a more impersonal and potentially alienating learning environment for students.

This highlights the need for a re-evaluation of the role and implementation of traditional pedagogical elements in contemporary architectural education. While the design studio and one-on-one teaching have long been cornerstones of architectural pedagogy, the diminishing resources and growing student numbers require new approaches to maintain the quality of education (Milliner, 2003). The integration of new technologies, such as immersive environments enabled by Virtual Reality (VR) and Augmented Reality (AR), could offer solutions to some of these challenges by providing more flexible, scalable learning environments without sacrificing the core principles of studio-based education (Whyte & Nikolić, 2018).

2.3.7 Influences of IT and CAD on Architectural Education

In contemporary education, the introduction of CAD technology has transformed many pedagogic approaches and methods. Digital technology has increasingly dominated the mental and operational landscape of everyday life, reshaping how architects design and communicate their ideas. Technology has rapidly changed the general vision of the world and experiences of daily life. As Spiridonidis and Voyatzaki (2007) state, “the applications of digital technology are not only powerful devices constituting the main tools for designing, modelling, and manufacturing architectural forms, but they are also powerful, efficient, and meaningful mediums for thinking about the field domain of their application” (p. 45). These tools influence how architecture is conceived, rethought, and experimented with, making it crucial for architectural education to adapt by integrating digital technologies systematically.

Integrating technology into architectural education requires the redefinition and reinvention of pedagogical frameworks, values, and principles. It demands new forms of knowledge, skills, and competencies as well as new tools, priorities, and preferences—establishing a new paradigm for architectural education. According to Spiridonidis (2007), “new values, aesthetic principles, and experimental forms are rapidly grounded in the consciousness of architects, having a profound impact on architectural education and the teaching process” (p. 47). As a result, the contemporary architectural design studio has been progressively transformed into an experimental lab, often dominated by computer labs or virtual workspaces where students can work remotely. Tutorials now often involve software-based presentations rather than relying on the traditional drawing board (Stevens, 2015).

However, it is worth noting that while digital presentations like PowerPoint are frequently used, many students come to tutorials with digital models (e.g., SketchUp) and face

challenges related to the technical limitations of the software or their lack of proficiency. This often leads to delays as students wait for their models to load or troubleshoot technical issues (Smith & Leung, 2019). The reliance on digital tools, while valuable, can also expose gaps in students' technical skills, which further complicates the integration of digital technologies into the learning process.

As technology continues to evolve, certain traditional practices, such as drawing and manual representation techniques, are becoming marginalized. For instance, the knowledge of a significant number of software programs is now a necessary condition for success in architectural education, which has reduced the emphasis on hand-drawn deliverables (Andia, 2013).

2.3.8 Education through Virtual Worlds

In the mid-2000s and early 2010s, research into the potential of using virtual worlds to enhance education gained popularity (Twining, 2010). Much of the work during this time focused on testing the efficiency and performance of virtual worlds in educational environments. These studies highlighted the importance of identifying the prevalent disciplines involved and understanding the distinct pedagogies associated with them. Jenkins and Zetter (2003) noted that “disciplines shape the nature of pedagogy, and such pedagogies reflect the practices and culture of the discipline” (p. 18). In architecture, these pedagogical reflections cross multiple disciplines, influencing how students are taught design, theory, and technical skills.

The majority of studies on virtual worlds have been conducted as testing grounds for traditional educational theories. For example, as mentioned in Section 2.1.6, the challenges posed by traditional education methods, such as limitations in technology, resources, and socio-economic conditions, made it difficult to fully test theories like

‘Total Studio’ or ‘Reflection-in-Action’ in their original forms. These theories, each with their own complexities, often required significant time, space, and resource commitments that were not feasible during the traditional period.

However, virtual worlds offer flexibility and potential to test these theories in ways that allow for more equitable evaluation. For instance, virtual environments enable the simulation of complex, real-world architectural problems that would otherwise be impractical to recreate in a physical setting (Smith & Jones, 2015). In the case of Total Studio, virtual worlds can simulate integrated, multidisciplinary collaboration, allowing students to work with specialists across environmental, structural, and technical disciplines. This eliminates the need for physical resources like space or materials, providing a controlled environment for students to experiment with interdisciplinary design without the constraints of real-world limitations (Whyte & Nikolić, 2018).

Building upon the framework of traditional theories, technological innovations such as VR and AR offer opportunities to create more efficient and updated teaching models. For example, Reflection-in-Action, which emphasizes real-time reflection and problem-solving during the design process (Schön, 1983), can be enhanced through the use of immersive technologies. In virtual environments, students can receive immediate feedback on their designs, allowing them to adjust their work in real time and reflect on their decisions more effectively (Twining, 2010). This type of immediate engagement with design problems enhances students’ ability to learn through doing, a key aspect of architectural education.

Furthermore, the use of virtual worlds is not limited to architecture. Disciplines such as engineering, medicine, and even business have adopted virtual environments for training and education (Baker & Thompson, 2017). Drawing from these disciplines, architectural education can learn how to integrate virtual environments to enhance collaborative

design, problem-solving, and interdisciplinary engagement, all of which are essential to modern architectural practice.

2.3.9 Influence of Video Games to Practice and the Gamer Generation

Luke Pearson's recent works and research support the notion that the gaming industry is transforming how people perceive architecture and design thinking. Pearson states that "game spaces offer new possibilities for architects to represent and realize projects as virtual worlds structured by computation. Game engine software is becoming increasingly democratized, and the two main platforms, Unity and Unreal, are both ostensibly available for free. In many ways, it has never been easier for an architect with an interest in the field of games to incorporate the design of virtual worlds into their practice" (Pearson, 2020, p. 15). Although Pearson's research primarily focuses on professional practice, it raises questions about education. Pearson suggests that the integration of game engines, technologies, and game design strategies into architectural practice is inevitable, leading us to question how these changes will impact architectural education.

Pearson also points out that "many of the formative experiences of architecture that young people have today are through video game worlds, and we can expect this to affect the aesthetic sensibilities of new generations of architects to come" (Pearson, 2020, p. 18). This suggests that the expectations and ambitions of the gamer generation may differ significantly from those of previous generations, and these differences will need to be addressed in the way education is delivered. As these new generations of students are exposed to architectural concepts through gaming, their approach to design may be more influenced by the virtual worlds they have engaged with than by traditional methods of architectural education.

Games incorporate narrative, fiction, and symbolic structures into their worlds, offering the potential to reinvigorate speculative design projects that have historically challenged the boundaries of architecture (Pearson, 2020, p. 22). As with previous technological advancements, the influence of video games on architectural practice will likely be translated into the educational setting. The challenge for educators is determining which methods and tools will be the most effective for incorporating these changes and under which pedagogical theories the integration of game design strategies will take place.

There are already examples of video games being used to teach architecture. Minecraft (2009), for example, has been utilized by organizations such as the RIBA and UN Habitat as an educational tool, where its first-person building mechanics recall pre-Renaissance construction, in which architects directed matters on-site (Pearson, 2020, p. 25). City-builder games like SimCity (1989-2014) and Cities: Skylines (2015) have also been discussed as useful educational tools, particularly in urban design and planning. These games allow players to simulate zoning and planning decisions, offering a systems-based approach to learning in which interrelated systems and causality play a central role (Lobo, 2008, p. 208). For example, a decision made regarding transportation infrastructure in SimCity may affect the development of housing, industry, and population growth. This ability to test hypotheses and explore cause-and-effect relationships makes such games valuable for teaching urban planning and architectural systems (Salen & Zimmerman, 2004).

One of the main arguments against purely speculative design (as discussed in Section 2.2.8) is that it often lacks consideration of real-world consequences. In video games like SimCity, consequences are inherent in the gameplay, as poor decisions lead to system failures or inefficiencies. This approach approximates real life, where architectural design decisions have lasting impacts on the environment, infrastructure, and society. In

contrast, speculative design within the traditional studio model, especially when dominated by the master-apprentice relationship, can sometimes focus too heavily on creativity and personal expression at the expense of understanding the broader consequences of design decisions.

With the help of virtual reality (VR) and augmented reality (AR), gaming technologies could provide real-life virtual simulations in education. These simulations could offer students a deeper and more engaging experience, allowing them to interact with their designs in real time and see the impact of their decisions in a controlled virtual environment. This level of interaction and consequence-based learning could address some of the issues related to engagement and efficiency in architectural education, moving beyond fantasy projects to more grounded and realistic design exercises (Whyte & Nikolić, 2018).

2.3.10 CAD & CAAD

Contemporary architectural education has been significantly influenced by the presence of CAD (Computer-Aided Design) and CAAD (Computer-Aided Architectural Design) systems (Mark, Martens, & Oxman, 2003). Before exploring their influences on education, it is essential to clearly define these two systems and their respective roles in design. CAD refers to software used to assist in the creation, modification, analysis, or optimization of a design, and is commonly used across various design fields including architecture, engineering, product design, and more. CAD systems provide a platform where design is executed using a database that incorporates both geometric data and object properties, which are manipulated via a graphical user interface (Kuna et al., 2018). In architectural practice, CAD software like AutoCAD and Revit allows architects to create detailed drawings and models with data associated with building components (e.g., materials, dimensions).

On the other hand, CAAD is a specialized subset of CAD tailored specifically for architectural design, integrating domain-specific knowledge and tools to enhance the architectural design process (Caetano, Santos, & Leitão, 2020). While CAD serves as a general design tool applicable to a range of fields, CAAD systems are developed with architectural thinking and problem-solving in mind, offering features that facilitate design exploration, development, and analysis within the specific context of architecture.

To clarify further, Computer-Aided Architectural Design (CAAD) encompasses any computational technique or software that actively supports and enhances the architectural design process, stimulating design thinking and enabling advanced workflows such as parametric modeling, form generation, and spatial analysis (Caetano et al., 2020).

In contrast, Computer-Aided Design (CAD) tools are typically used for representing and visualizing designs that have already been conceptualized, focusing primarily on technical drafting and documentation rather than on the generative and analytical aspects of design thinking. For example, while a CAD tool like AutoCAD is commonly used to create precise technical drawings of completed designs, CAAD tools such as Rhino (with Grasshopper as a parametric scripting extension) allow designers to generate complex forms, perform real-time environmental simulations, and explore multiple design variations interactively. Other CAAD software, such as Generative Components (Bentley Systems) or Autodesk Revit with Dynamo, similarly enable architects to integrate computational logic into the design process, bridging conceptual exploration with performance-driven decision-making.

This distinction highlights the fundamental difference in workflow, where CAD primarily supports representation and documentation, CAAD facilitates computational design thinking, enabling architects to engage with adaptive, data-driven, and interactive design

methodologies. The distinction between CAD and CAAD can sometimes appear blurred to those unfamiliar with their applications. However, the key difference lies in their purpose: If a system serves to enhance, stimulate, and develop design thinking during its use, it is more accurately classified as CAAD. If the system is primarily used to represent and communicate a developed design without influencing the design process itself, it is classified as CAD (Oxman, 2008).

2.3.11 Emergence of CAAD

Along with the previously studied theoretical aspects and historical context of architectural pedagogy, it is essential to examine the impact and conception of CAAD in architectural education. CAD's influence on architectural curricula can generally be divided into two phases: the era of CAD tools (1950-1980) and the introduction of additional CAD courses to traditional curricula (1985-1995) (Norrie, 1985). During the early era, CAD was often integrated into architectural education through experimental courses or embedded within other design-oriented courses, but it was primarily viewed as a technical support tool rather than a design medium (Bremer, 2007).

During this first phase, the success of CAD courses depended heavily on the teacher's familiarity with the technology and their personal teaching style (Norrie, 1985). Teachers who were more technically inclined or enthusiastic about technological advancements tended to explore CAD's potential in their courses, while others remained focused on traditional hand-drawing methods. The primary concentration during this time was on understanding the technical aspects and capabilities of CAD tools, with an emphasis on learning to use the software rather than incorporating it as part of the design process (Bremer, 2007).

In the mid-1980s, CAD began to evolve into what would later be known as CAAD, specifically tailored to architectural practice. As CAD gained popularity in professional

practice, architectural schools started to establish specialized CAD curricula as distinct divisions within their departments (Penttila, 1996). By the early 1990s, the distinction between CAD and CAAD became more pronounced. While CAD was viewed primarily as a tool for drafting and visualization, CAAD began to be recognized as a system that incorporated computational techniques to enhance architectural design thinking and professional practice (Caetano, Santos, & Leitão, 2020). This shift reflected a deeper understanding of how computational tools could be integrated into architectural education to support not just technical representation but also the creative design process.

The period after 1995 marked significant advancements in both software and hardware that further solidified the role of CAAD in architectural education. The early 1990s saw the development of the first commercially available 3D systems, such as 3D Studio (later 3D Studio Max), alongside popular CAD systems like AutoCAD and Microstation (Bridges & Powell, 1995). These programs introduced 3D modeling capabilities that allowed architects and students to move beyond 2D drafting into fully realized digital models. However, the hardware required to run these programs—often expensive UNIX-based systems—was a limiting factor, making widespread adoption in education slow at first.

At the same time, there was a notable shift away from live testing environments, such as building labs and environmental simulation labs, which had been used for testing structural and environmental systems in architectural education. This shift occurred in parallel with the rise of digital tools, as live testing became less feasible due to the high cost of maintaining these labs and the growing reliance on virtual simulations (Bridges & Powell, 1995). By the mid-1990s, the first iterations of BIM (Building Information Modeling) software, such as AutoCAD AEC and the 3D version of AutoCAD AME, were

introduced, though they were notoriously difficult to use (Powell & Clark, 1995). Around this time, VR (Virtual Reality) technologies also began to emerge in the architectural domain, further expanding the possibilities for design visualization and experimentation. These developments during the 1990s coincided with the beginning of the internet revolution, though the internet was still in its early stages. Dial-up modems and limited access to computers in architectural offices and universities meant that digital tools were often shared among multiple users, slowing progress in integrating these tools into everyday practice (Powell & Clark, 1995). Nonetheless, the seeds of modern CAAD education had been planted, and as hardware became more affordable and software more user-friendly, CAAD systems became a fundamental component of architectural education and practice

2.3.12 Past Predictions and Comparisons

In addition to the historical context discussed earlier, several predictions and comparisons regarding how CAAD would influence architectural education have been made over the years. Cheung and Slavin (2013) proposed three distinct development paths for CAAD integration in education: neutral, positive, and negative. These paths reflect different perspectives on how CAAD could evolve and impact pedagogy.

Firstly, the ‘neutral development path’ emphasizes a gradual transition from traditional methods to CAAD, focusing on maintaining continuity with established pedagogies. This approach proposes building on the foundations of traditional design philosophies rather than imposing entirely new methods. This softer transition is aimed at easing the generational gap that often arises when new technologies are introduced too abruptly (Mark, Martens, & Oxman, 2003). The goal of this approach is to integrate CAAD incrementally, allowing students and educators to adapt without major disruptions while still benefiting from the capabilities of digital design tools (Bremer, 2007).

Secondly, the ‘positive development path’ views CAAD integration as essential for staying competitive in a rapidly evolving architectural industry. This perspective argues for a comprehensive and immediate adoption of CAAD technologies, driven by the constant pressure to innovate and improve efficiency in architectural practice (Kalay, 2006). The positive path highlights the potential for CAAD to push the boundaries of architectural design by enabling architects and students to test the limits of computational tools and explore new ways of thinking about space and form. This path supports the idea that staying at the forefront of technology is crucial for both educational institutions and the profession as a whole (Schnabel & Kvan, 2003).

Lastly, the ‘negative development path’ warns of the risks and challenges that can arise from the rapid and uncoordinated adoption of CAAD without sufficient planning and cohesion. One of the main concerns raised by this perspective is the significant number of resources required to implement and maintain CAAD systems in educational settings (Penttila, 1996). This path also highlights the potential clash between older architects, who rely on traditional methods, and younger, digitally-savvy students, which could create a divide between technical proficiency and foundational design knowledge (Lawson, 2006). Additionally, this path cautions against the possibility of students relying too heavily on digital tools, prioritizing speed and efficiency over deeper learning experiences and the mastery of core design principles (Picon, 2013).

Cohesion is a significant concern in the negative path, particularly regarding how well CAAD is integrated into the broader educational framework. Without careful planning and sufficient resources, the introduction of CAAD could lead to fragmented learning experiences, where students excel in using digital tools but lack the comprehensive understanding of design theory and principles required for professional practice (Cheung

& Slavin, 2013). This fragmented approach risks creating a disconnection between the technical aspects of architecture and the conceptual, creative side, which has long been the hallmark of traditional architectural education (Oxman, 2008).

In conclusion, the debate over the integration of CAAD into architectural education presents multiple challenges and opportunities. The neutral path offers a balanced approach, preserving the strengths of traditional education while introducing digital tools incrementally. The positive path advocates for rapid adoption to stay competitive, while the negative path warns of potential risks and a lack of cohesion in educational approaches.

For this PhD research, the relevance lies in understanding which path or combination of paths is most suitable for contemporary architectural education. As immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) become more prevalent, the question arises whether these tools should be introduced incrementally, as in the neutral path, or rapidly, as in the positive path. This research will explore how these technologies can be integrated into design education without sacrificing the depth of learning that comes from mastering traditional principles, addressing concerns raised in the negative path about the potential loss of foundational knowledge (Whyte & Nikolić, 2018).

2.3.13 Prior Knowledge and Challenges

One of the primary challenges with CAAD in architectural education is the importance of prior knowledge and skills in computing. Although this issue is less pronounced today, as computers and IT are integral to everyday life, the early stages of CAAD adoption faced significant hurdles related to both student and staff training (Botchway, 2016). Initially, many students and tutors lacked the computing skills necessary to effectively use CAAD

systems, and early proposals sought to bridge this gap through optional classes designed to ensure basic competency in using the software (Salman, Laing, & Conniff, 2014).

These early bridging classes often focused on developing basic computer skills, such as learning how to use the software, rather than exploring the broader potential of CAAD in design or education (Botchway, 2016). The main objective of these courses was to provide students and staff with the functional knowledge required to operate the software. However, this approach has been criticized for promoting a “how-to-use-the-software” mindset rather than encouraging students to explore how these tools could be used to enhance their design thinking and architectural education (Kuna et al., 2018). As a result, these classes often produced students with technical skills but limited understanding of how CAAD could influence design creativity and innovation.

The second challenge was integrating CAAD into the architectural curriculum in a way that ensured relevance to architectural design, rather than treating CAAD simply as a technical drafting tool. This challenge required IT classes to be customized and aligned with architectural pedagogy so that students could understand not only how to use the software but also how it could enhance their design process (Salman et al., 2014). A key part of this integration involved developing good computing habits that increased efficiency and productivity while enhancing the use of computers as creative tools in the design process.

When teaching CAAD, it is essential to distinguish between skill acquisition and knowledge development. If the focus is solely on skill, then the educational value of CAAD diminishes, as it becomes more akin to training draftsmen rather than fostering architects who can think critically and creatively (Kuna et al., 2018). While technical skills are undoubtedly important for managing expensive and scarce resources and for achieving proficiency in software, focusing on knowledge and design thinking provides

deeper advantages by stimulating interest, fostering creativity, and improving the overall quality of architectural design (Mark, Martens, & Oxman, 2003). This approach allows students to see CAAD not just as a tool but as a medium for innovation and exploration in design.

Both technical skills and creative knowledge are essential when teaching Computer-Aided Architectural Design (CAAD), but the key is finding a balance between the two. General knowledge refers to a broad base of factual, theoretical, and procedural information applicable across disciplines, whereas creative knowledge involves the ability to generate original ideas, solve problems innovatively, and apply critical thinking within a specific domain (Runco & Jaeger, 2012). In architecture, creativity is not only valued but fundamental to the design process, distinguishing routine drafting from innovative spatial and structural solutions.

Creative knowledge is particularly emphasized in architectural education because design thinking requires students to go beyond technical execution and engage in conceptual exploration, problem-solving, and experimental iteration (Cross, 2006). Unlike engineering or construction fields, where precision and technical accuracy dominate, architecture operates at the intersection of function, aesthetics, and human experience, making creative adaptability essential. CAAD plays a crucial role in this by allowing students to test design variations, simulate spatial experiences, and explore unconventional forms that would be difficult to visualize using traditional methods (Kuna et al., 2018).

Beyond academia, creativity is also socially and professionally prioritized in architecture due to the evolving urban, environmental, and technological challenges of the built environment. Architects must respond to climate adaptation, cultural identity, and user experience, requiring creative approaches to sustainable and responsive design (Salman

et al., 2014). In professional practice, creativity drives innovation in materials, structures, and digital fabrication techniques, shaping the future of architectural discourse.

Therefore, CAAD education should not only provide students with technical proficiency but also encourage them to use digital tools as platforms for creative exploration. This dual focus ensures that students are not only competent in using software but also capable of leveraging computational design processes to push the boundaries of architectural practice (Mark et al., 2003). The integration of CAAD into design pedagogy reinforces the notion that digital tools are not mere drafting instruments but catalysts for design thinking and spatial innovation.

2.3.14 Passive Learning Vs Active Learning

In recent years, the rush to engage with digital media due to pressures from both culture and the market has led to significant challenges for CAAD integration. Across Europe, the majority of architectural schools have struggled with these pressures, as there has been a separation in approaches to CAAD education (Cimadomo, 2014). This separation refers to the different ways in which CAAD is incorporated into architectural curricula. Due to the demands of the market and professional practice, many schools accelerated the integration of CAAD, often teaching it as an additional course rather than incorporating it fully into the design studio (Salman, Laing, & Conniff, 2014).

While this approach allows students to gain more in-depth familiarity with design tools, it often results in students lacking practical and coherent knowledge that integrates with the overall design process (Symeonidou, 2017). As discussed in previous sections, students risk becoming drafters rather than architects, focusing on technical skills rather than creative problem-solving (Kuna et al., 2018). The rush to include as many CAAD-facilitated features as possible has led to a disconnection between the design process

and construction. This gap is largely due to issues related to the transfer of information, feasibility, and technical competence (Han, 2006).

Moreover, the architecture curriculum is already packed, given the extensive knowledge that students need to acquire. The introduction of CAAD into this already dense curriculum presents a significant challenge: what should be removed to make space for it? Balancing CAAD with other essential components of the curriculum requires careful consideration to avoid overwhelming students or sacrificing important aspects of architectural education (Cimadomo, 2014).

In architectural education, active learning, particularly in the design studio, is essential for students to fully grasp the complexities of architecture. As Self and Walker (2010) noted, “architecture is only ever learned by getting your hands dirty” (p. 58), and the design studio remains the best place to exercise this active, hands-on approach. Interestingly, when reviewing the literature on CAAD, there is a recurring notion of returning to practice-based and experimental education, often referencing the BAUHAUS model due to its emphasis on active learning (Symeonidou, 2017). The BAUHAUS philosophy promotes learning by doing, which is increasingly seen as an important counterbalance to the more passive learning that CAAD software can sometimes promote.

The notion of hands-on learning is also echoed in the work of Montessori, who emphasized the importance of learning through experience: “He does it with his hands, by experience, first in play and then through work. The hands are the instruments of man’s intelligence” (Montessori & Chattin-McNichols, 1995, p. 134). While this quote highlights the value of active learning, it may be more appropriate to include in the literature review, as it provides a foundational understanding of educational theories that can inform architectural pedagogy.

The key challenge in integrating CAAD into architectural education is finding the right balance between passive learning (technical skills) and active learning (creative problem-solving and hands-on experience). While CAAD offers powerful tools for drafting and visualization, it is essential to ensure that students are not merely learning to use software but are also developing the critical and creative thinking skills necessary for architecture. Research suggests that integrating CAAD fully into the design studio, rather than as a separate course, can help bridge the gap between digital tools and the hands-on nature of architecture (Self & Walker, 2010; Salman et al., 2014). However, achieving this integration requires careful restructuring of the curriculum to ensure that it does not become overcrowded, as the architecture curriculum is already dense and filled with essential knowledge (Cimadomo, 2014; Symeonidou, 2017).

2.3.15 CAAD Design Tools

The evolution of innovative CAD software and advancements in hardware have made it feasible to create complex forms and experimental designs. In both professional practice and academia, the extensive use of digital media and CAAD software has helped shape digital architecture into its own distinct entity (Lansdown & Maver, 1984). Beyond aesthetics, CAAD software has become the foundation for efficient data management and data collection, allowing architects to handle large volumes of design data with greater ease. Due to the complexity of many modern designs, traditional methods and tools often reach their limits at certain stages, making CAAD essential for continuing the design process (Veisz et al., 2012).

However, there is a danger in becoming overly dependent on CAD tools. When dealing with extremely complex designs, there is a risk that the software may take control away from the architect, allowing the design to dictate decisions rather than the designer (Ashton, 1995). This lack of control can cause the quality of the design to suffer, as

architects may rely too heavily on automated processes without fully understanding or refining the design themselves. Veisz et al. (2012) argue that to avoid this risk, it is essential to rethink design methodology when teaching CAD software. Rather than simply teaching students how to use specific software, architectural education should focus on developing new ways of thinking that exploit the full potential of these tools in an integrative design process. This approach ensures that students are equipped with the problem-solving skills necessary to maintain control over complex designs, rather than becoming overly reliant on the software (Leinonen, 2010).

The increasing sophistication of software and hardware presents both opportunities and challenges in architectural education. In European schools of architecture that adopt a more technical curriculum, students who possess broad computer skills are more likely to thrive (Güney, 2015). However, this focus on technical skills has led to criticism from professional practices, who argue that university graduates are increasingly incapable of visualizing and understanding complex designs (Fricker et al., 2013). This criticism echoes similar concerns raised during the transition from classical to traditional pedagogy, in which the integration of technology and industrialism was not properly addressed. As discussed in Section 2.2.2, the shift from the master-apprentice model to formalized institutional education faced challenges in aligning new technologies with traditional methods. Similarly, the current evolution of CAAD in architectural education has led to a gap between technical skills and creative, holistic design thinking (Penttilä, 1996). This disconnect poses ongoing issues for architectural pedagogy as it seeks to integrate technological advancements effectively.

The challenge for architectural education is to strike a balance between the benefits of increasingly sophisticated CAAD tools and the need to maintain design control and creativity. While CAAD offers immense potential for managing complexity and enhancing

design possibilities, it is crucial that students are not merely trained to use software but are also taught how to think critically about their designs and maintain control throughout the process (Leinonen, 2010; Veisz et al., 2012). The criticisms from professional practice mirror the challenges faced in earlier transitions in architectural pedagogy, highlighting the need for better integration of technology within a broader design methodology (Fricker et al., 2013; Penttila, 1996).

2.4 Conclusions

Having reviewed the literature on traditional pedagogy, several conclusions can be drawn regarding its evolution and relevance to architectural education. For anyone wishing to study, research, or work in architectural pedagogy, it is imperative to understand the significance of design studio teaching as the central element of architectural education. Throughout the last three centuries, numerous pedagogical elements and methodologies have been introduced, modified, and, in many cases, removed. Since the inception of the *École des Beaux-Arts*, many of these elements have diminished or been replaced, yet the design studio remains the core principle around which all other systems and methods are built (Schön, 1983). Any systems or elements devised outside the studio environment tend to function as satellite modules that often prove inefficient in delivering a holistic learner experience (Nicol & Pilling, 2000).

If the aim is to introduce new elements or methods that address emerging socio-political changes or technological advancements, it is crucial to evaluate how these proposals can be integrated into the design studio model. Architectural education continues to face external pressures, such as the ongoing influence of agendas like Widening Participation and Enhancement, which have impacted the direction of pedagogy (Thomas & Quinn, 2007). However, these agendas have only partially dictated the course of education, as the need for reform and adaptation persists in response to the evolving needs of the profession and society (Salman et al., 2014).

The COVID-19 pandemic initiated a series of changes that architectural education was unprepared for, prompting the adoption of teaching methods like online tutorials and virtual critiques, which were not widely used before. Although the pandemic highlighted the limitations of the physical studio environment, it also opened up new avenues for teaching and learning that warrant further exploration. These developments, along with future pandemic planning, suggest that the lessons learned during the pandemic will continue to shape the future of architectural pedagogy.

As we now enter a period of uncertainty and discovery, architectural education is on the verge of tectonic-level changes driven by technological advancements, particularly in immersive technologies such as VR and AR. These tools offer the potential to revolutionize the design studio by addressing some of the long-standing challenges, such as declining physical resources and the inefficiencies of traditional satellite modules. Just as CAAD transformed architectural education by integrating digital tools into design processes, VR and AR hold the potential to bring about similar shifts, allowing for more immersive, interactive, and dynamic learning experiences (Whyte & Nikolić, 2018).

However, it is crucial to learn from the mistakes made during the early adoption of CAAD. The rush to adopt digital tools led to gaps in delivering a high-quality learner experience, with many students focusing on mastering the software rather than developing the creative problem-solving skills required in architecture (Fricker et al., 2013). To avoid similar pitfalls, this PhD research will study CAAD and related fields closely, analyzing previous works and using them as case studies to inform the integration of VR and AR into architectural education. This approach will help ensure that the introduction of immersive technologies is grounded in pedagogical principles that prioritize critical thinking, creativity, and hands-on experience.

This chapter has posed several important questions regarding the evolution of architectural pedagogy, the role of technological advancements, and the integration of new methods into the

design studio. It has provided insight into how architectural education has responded to external pressures and has examined the potential impact of VR and AR on the studio model.

In Chapter 3, the first part will explore the theory of play and learning, investigating how these theories support creative and experiential learning, and their relevance to architectural education. The second part will build on this foundation by reviewing research that has been conducted on integrating immersive technologies such as VR and AR into education, both within architecture and other fields. This chapter will address key questions such as: What pedagogical value do immersive technologies bring to the learning environment? How can these tools be effectively integrated to enhance design education? And what lessons can be drawn from other fields that have successfully adopted immersive technologies in educational settings?

Chapter 3: Context of Research

3.0 Introduction

This chapter explores the integration of immersive technologies—namely Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—within architectural education. Building on the foundations established in the previous chapter, which focused on the historical evolution of architectural pedagogy and the integration of technological advancements such as CAAD, this chapter examines the potential of these emerging technologies to transform the learning environment. The application of immersive technologies in education is not just a response to technological trends but a fundamental shift in how students engage with architectural design, spatial concepts, and problem-solving skills.

The relevance of this chapter lies in addressing key research questions posed in Chapter 1, specifically: What pedagogical value do VR and AR bring to architectural education? and how can these technologies be effectively integrated into the studio model to enhance learning outcomes? By investigating the role of VR, AR, and MR in education, this chapter will explore how these technologies can overcome current limitations in traditional teaching methods and offer more interactive, experiential learning environments.

Augmented Reality (AR) involves the integration of real and virtual interactions, combining them to create a system that supports real-time interaction and 3D registration (Kato, 2012). Despite their recent surge in popularity due to advancements in commercial technology, the concepts of VR and AR have been in development for several decades (Azuma, 1997). Virtual Reality (VR), characterized by its immersive and interactive nature, strives to create highly persuasive virtual environments where users can deeply engage with simulated realities.

For those unfamiliar with VR and AR, their applications in architecture may sometimes be perceived as primarily limited to enhancing visualization for marketing strategies or creating immersive experiences in video game development (Wang, 2009). However, this perception does not reflect the full scope of their potential applications. Beyond these commercial uses, VR and AR offer significant possibilities in academic fields—especially in architectural education—where they can enhance spatial understanding, provide new methods for design experimentation, and offer novel ways of interacting with digital models. The academic field, however, presents challenges, particularly due to the ambitious visions associated with using immersive technologies to improve learning outcomes (Belcher & Johnson, 2008).

The emergence of Mixed Reality (MR), which blends elements of VR and AR, further broadens the scope of immersive technologies in education. MR integrates the immersive qualities of VR with the contextual awareness of AR, offering a more interactive and integrated learning experience (Azhar & Kouider, 2021). This hybrid approach holds significant promise for architectural education, where the ability to seamlessly transition between the physical and virtual worlds can provide students with a richer, more dynamic understanding of spatial relationships and design processes.

3.1 Immersive Technologies Background and Rationale

This chapter explores the effectiveness and impact of implementing VR, AR, and other immersive technologies across various pedagogical models in architectural education. Building on the insights from Chapter 2—which addressed the historical evolution of architectural pedagogy and the integration of digital tools like CAAD—this chapter focuses on how VR and AR can further revolutionize the design studio environment by providing immersive, interactive learning experiences (Whyte & Nikolić, 2018; Oxman, 2008). Immersive technologies are recognized for their potential to foster deeper engagement with architectural concepts by enabling students to interact directly with spatial models and complex designs in ways that traditional teaching

methods cannot offer (Buchanan, Mann, & Perner, 2013). This exploration is directly linked to the research question posed in the introduction: How can immersive technologies be integrated into architectural education to enhance student engagement and improve learning outcomes?

By examining the experiences of both students and tutors across universities with diverse pedagogical approaches, this research aims to offer a comprehensive understanding of how VR and AR can be integrated into established educational systems (Christopoulos, Conrad & Shukla, 2018). Studies have shown that immersive technologies in education can significantly improve learner engagement, motivation, and performance, particularly in disciplines like architecture where spatial understanding and design thinking are central (Azuma, 1997; Whyte & Nikolić, 2018). Furthermore, this chapter will consider how the use of these technologies may lead to the development of new pedagogical methods that rely more heavily on immersive environments (Buchanan et al., 2013).

A significant focus of this research is on student engagement and its correlation with educational outcomes. Research indicates that students who are engaged and excited about their subject tend to perform better academically, as they interact more deeply with the material and develop stronger conceptual understandings (Christopoulos et al., 2018). This is particularly relevant for students who may struggle with traditional, two-dimensional methods of teaching but thrive when provided with innovative, interactive tools (Oxman, 2008).

The COVID-19 pandemic highlighted both the limitations and opportunities of two-dimensional, screen-based communication in educational contexts. With students and educators restricted to digital screens, the absence of traditional, physical learning environments led to a growing demand for more interactive and engaging digital alternatives. This deprivation of hands-on, spatial, and collaborative learning experiences made immersive technologies increasingly attractive, as they provided a means to simulate physical presence and interaction in virtual settings.

The shift to online learning exposed the limitations of passive, screen-based instruction, reinforcing the need for dynamic, experiential learning environments that could bridge the gap between physical and digital spaces. VR and AR emerged as particularly promising solutions, offering new ways for students to interact with 3D models, engage in simulations, and collaborate in shared virtual environments, helping to address some of the challenges posed by traditional remote learning methods (Buchanan et al., 2013).

While this surge in interest was initially driven by the necessity of overcoming pandemic-related restrictions, the success of immersive platforms in enhancing spatial understanding, creativity, and collaboration suggests that their role in education will continue to expand beyond the constraints of the pandemic.

Although the focus of this research is on immersive technologies like VR and AR, other technologies, such as holography, have also gained attention as potential tools for creating more interactive and engaging learning experiences. Holography, first developed by Dennis Gabor, has evolved with advances in lasers and imaging technology, offering novel ways to visualize complex architectural designs (Johnston, 2016). However, for the purposes of this research, VR and AR are prioritized due to their more established pedagogical basis and widespread use in educational institutions. The increasing availability of affordable, high-quality devices like the Oculus Rift and Microsoft HoloLens makes VR and AR more accessible, enabling a broader range of students to benefit from immersive learning environments (Buchanan et al., 2013).

In this chapter, we will assess the role of VR and AR in addressing the challenges highlighted in Chapter 2, such as the need for more integrative, hands-on learning experiences and the limitations of traditional studio environments. Rather than treating engagement as the primary outcome, this chapter explores how immersive technologies can be leveraged to enhance spatial understanding, foster creative knowledge acquisition, and facilitate critical thinking through experiential learning.

While engagement is an important factor in technology adoption, this research argues that its significance lies in its ability to create learning conditions that support deeper cognitive processes. By providing interactive, immersive experiences, VR and AR offer new ways for students to explore spatial concepts, experiment with iterative design strategies, and collaborate more effectively in a virtual studio environment. In this sense, enhanced engagement is not the final goal but rather a catalyst for improving architectural education outcomes.

3.1.1 History of Virtual Reality

Virtual Reality (VR) has the potential to significantly transform architectural education by providing immersive and interactive experiences that were previously impossible. While VR has not yet achieved widespread integration in mainstream architectural education, its capabilities offer promising avenues for enhancing student engagement and understanding of complex spatial designs. This section explores the history of VR, its development, and its gradual integration into architectural education, highlighting key milestones and technological advancements along the way.

The conceptual origins of VR can be traced back to the 1960s. Morton Heilig, a cinematographer, invented the Sensorama, a mechanical device designed to immerse users in a multisensory environment, providing visual, auditory, and tactile experiences (Heilig, 1962). This pioneering work set the stage for subsequent developments in VR technology, which would gradually evolve over the next few decades.

In 1968, Ivan Sutherland created the first head-mounted display system known as the “Sword of Damocles.” This system introduced the concept of virtual environments viewed through a headset, laying the groundwork for future VR technologies (Sutherland, 1965). Sutherland’s invention was a significant leap forward, although it was limited by the technology of the time.

The 1980s and 1990s saw significant advancements in VR technology, particularly with the development of more sophisticated headsets and motion-tracking systems. VPL Research introduced the Data Glove in 1987, allowing users to interact with virtual environments using hand movements, adding a new dimension to the VR experience (Pimentel & Teixeira, 1995). During this period, VR became more visible in academic research and select industries, including gaming and simulation, though its use remained largely experimental due to the high cost of hardware and software.

Several key developments during the 1990s helped raise awareness of VR, though mainstream adoption remained elusive. Nintendo's release of the Virtual Boy and the Power Glove gained attention, despite their commercial struggles. Additionally, Virtual I-O introduced i-glasses, which offered a more affordable VR experience compared to some of the high-end alternatives (Pimentel & Teixeira, 1995). Sony also entered the market with their own VR glasses, and various other technologies emerged, such as the Polhemus Isotrak and Fastrak tracking systems, which enabled more precise interactions in virtual environments. However, these technologies were expensive and required specialist knowledge to integrate hardware, software, and coding systems for VR environments (Woolley, 1997).

At the high end of VR development, immersive environments such as CAVES (Cave Automatic Virtual Environments) emerged, with installations at institutions like Salford and UCL in the UK. Powered by Silicon Graphics Reality Engines, these systems offered immersive, large-scale virtual environments that pushed the boundaries of VR technology, though their use was limited to well-funded research institutions due to their cost, which often ran into the millions (Cruz-Neira et al., 1993).

As VR technology continued to evolve into the early 21st century, advancements in computing power, graphics processing, and affordable headsets such as the Oculus Rift

and HTC Vive marked a turning point. Today, VR technology is far more pervasive and affordable, allowing for broader use in both academic and professional settings (Whyte & Nikolić, 2018). Architectural education is beginning to explore how VR can enhance learning, particularly by providing students with the ability to interact with complex 3D models in immersive environments, although the technology is still not universally adopted.

While the early history of VR was marked by high costs, complex setups, and limited user bases, the modern era has seen VR become more accessible to a wider audience, including educational institutions. The next challenge lies in effectively integrating this technology into architectural pedagogy to realize its full potential for enhancing design education.

3.1.2 Notable Applications and Research of Virtual Reality

The history of VR has played a pivotal role in shaping how this technology is used in architectural education today. Understanding the evolution of VR helps us recognize how early innovations have informed the development of more sophisticated pedagogical applications, particularly in how students engage with architectural design. The high costs and technical challenges of early VR systems limited their use to research institutions and select industries. However, as VR technology has become more accessible, educators have begun exploring how to integrate VR into architectural pedagogy to enhance learning outcomes and provide students with a more interactive, immersive experience (Whyte & Nikolić, 2018).

Various studies have now highlighted the benefits of integrating VR into architectural education. For instance, Abdelhameed (2011) found that VR significantly augmented students' creativity, particularly in the final stages of design. Despite earlier technological limitations, VR enabled students to gain spatial insights by "walking

through" their designs—an experience that traditional two-dimensional drawings or models could not provide (Campbell & Wells, 2001). This highlights VR's potential to bridge the gap between theoretical concepts and practical, experiential learning, an essential component in architecture education.

Recent advancements in both VR hardware and software have allowed for more complex and dynamic uses of the technology in the classroom. These developments have expanded the scope of VR applications beyond simple visualizations, incorporating additional objectives and tools such as agent-based modeling and biometric feedback. For example, Huang et al. (2018) used agent-based modeling in VR to simulate user interactions within designed spaces, providing students with deeper insights into spatial usage and design efficiency. Such simulations allow students to evaluate their designs in real time, offering an unprecedented level of interactivity.

Additionally, Zhang et al. (2018) incorporated biometric feedback to assess emotional and physiological responses to architectural designs. Integrating biometric sensors into the VR experience allows students and educators to better understand how users physically and emotionally react to a given space, providing a novel approach to evaluating user experience in architectural design.

3.1.3 Current State and Future Directions of Virtual Reality

Today, the integration of Virtual Reality (VR) and Augmented Reality (AR) into architectural education is gaining momentum, though evidence of their widespread use varies across institutions. While not yet ubiquitous, certain educational programs are embracing these technologies, offering interactive and collaborative capabilities that enhance the educational experience (Whyte & Nikolić, 2018). Modern VR platforms like Gravity Sketch facilitate real-time modifications and collaborative design sessions, allowing VR to function not only as a visualization tool but also as a platform for conceptual design and

iterative development (Huang et al., 2018). However, despite the potential, the adoption of VR and AR remains uneven, and more empirical research is needed to fully understand their current impact in education.

Recent studies have explored the use of VR in early-stage design processes, leveraging its interactive capabilities to facilitate brainstorming and conceptual exploration. Huang et al. (2018) demonstrated that using VR to simulate user interactions within designed spaces allowed students to receive real-time feedback on spatial usage and design efficiency, thereby enhancing the design process. The study concluded that VR provided a more dynamic, iterative process for refining architectural designs compared to traditional methods. Similarly, Zhang et al. (2018) incorporated biometric feedback within VR environments to measure emotional and physiological responses to architectural designs. Their study concluded that this approach offered valuable insights into user experience, encouraging students to consider not just the physical aspects of a design but also how it affects occupants on an emotional and physiological level.

Despite these promising applications, VR is not yet fully integrated into most architectural education programs. Several challenges remain, including the high cost of equipment, the need for specialized training, and the lack of standardized approaches to integrating VR into the curriculum. As noted by Buchanan et al. (2013), while VR has shown potential for transforming how students interact with spatial designs, there is still a long way to go before it becomes a core component of architectural pedagogy across institutions.

Beyond architecture, VR has demonstrated significant value in other educational fields, providing insights that could inform its broader integration into architecture education. In medical training, for example, VR is used for surgical simulations, allowing students to practice complex procedures in a risk-free environment (Loke et al., 2019). Studies have

shown that these simulations improve students' procedural skills and confidence levels, offering a more immersive and practical learning experience compared to traditional methods (Brown et al., 2020). Similarly, in engineering education, VR has been used to teach students how to operate machinery and navigate hazardous environments, enhancing safety and learning outcomes (Liu et al., 2017). These applications highlight VR's versatility and underscore its potential to be used in architectural education for tasks such as construction simulations or real-time environmental analysis.

As VR and AR technologies continue to evolve, their potential to transform education will only grow. The future of architectural education is likely to be significantly influenced by these technologies, providing students with more immersive, interactive, and engaging learning experiences (Whyte & Nikolić, 2018).

However, realizing this potential requires overcoming key challenges, particularly in developing standardized pedagogical frameworks and ensuring that educators are adequately trained to implement immersive technologies effectively. Unlike traditional teaching methods, VR-based learning demands new instructional strategies that integrate experiential learning, real-time collaboration, and spatial cognition techniques. Without a clear, standardized framework, the integration of VR and AR into curricula risks being inconsistent and fragmented across institutions (Buchanan et al., 2013).

Similarly, specialized training for educators is critical to bridging the gap between technological potential and practical application. Many architectural educators lack formal training in immersive technologies, which can create barriers to adoption and limit the effectiveness of VR-based pedagogy. Establishing professional development programs and pedagogical guidelines will ensure that educators are equipped with the necessary skills to leverage VR as a transformative tool for design education.

As VR becomes more accessible and integrated, its impact on education will expand, creating new opportunities for experiential learning, critical thinking, and innovation. By addressing the need for structured pedagogical frameworks and educator training, institutions can maximize the benefits of immersive technologies and ensure that all students have equal opportunities to engage with these tools effectively.

3.1.4 History of Augmented Reality

As Virtual Reality (VR) technology was developing, Augmented Reality (AR) began to take shape, evolving along a parallel path. The term “Augmented Reality” was coined in 1990 by Tom Caudell, a researcher at Boeing, to describe a digital display that overlaid information onto the real world to assist workers with complex assembly tasks (Caudell & Mizell, 1992). Early AR systems were primarily used in industrial and military applications, where they provided real-time information overlays to support intricate operations and improve the efficiency of tasks like equipment assembly and maintenance.

One of the pivotal moments in AR’s development came with the introduction of the ARToolKit by Kato and Billinghurst in 1999, an open-source library that democratized AR development by making it accessible to a broader range of developers (Kato & Billinghurst, 1999). The outcome of their research was that ARToolKit allowed developers to overlay virtual images on physical objects using a simple marker-based tracking system, opening up AR for educational, industrial, and consumer applications. This toolkit, along with advancements in computer vision technology, significantly contributed to AR’s evolution beyond niche industrial uses into a wider range of fields.

The widespread adoption of smartphones in the late 2000s further accelerated AR development. The powerful mobile devices, equipped with improved cameras and graphics processing capabilities, made AR applications more accessible to the general

public (Billinghurst et al., 2015). This shift allowed AR to expand into consumer markets, including education, retail, and entertainment, where it provided users with interactive, real-time experiences. The research concluded that smartphones democratized AR by making it mobile and accessible, with numerous applications emerging in everyday life, such as AR-enabled shopping experiences and navigation systems.

As AR technology advanced, its applications in education also began to emerge, providing new tools for learning that blended digital content with the physical world. AR's potential to enhance education lies in its ability to offer real-time, interactive experiences that engage students and allow them to visualize complex concepts (Azuma, 1997). This feature has made AR particularly appealing for architectural education, where visualizing spatial designs and contextualizing digital models in the physical environment is a key part of the learning process.

3.1.5 Impact of Technological Progress & Availability for AR

The development of Augmented Reality (AR) throughout the 1990s and early 2000s was marked by significant technological progress, particularly in computer vision, graphics, and mobile computing. One of the major milestones during this period was the introduction of ARToolKit by Kato and Billinghurst in 1999. This open-source library provided developers with the tools to create AR applications more easily, effectively democratizing AR development and expanding its potential applications across industries (Kato & Billinghurst, 1999).

However, it was not until the late 2000s, with the widespread adoption of smartphones and advancements in graphics processing units (GPUs), that AR began to gain mainstream traction. Smartphones, equipped with high-resolution cameras, sensors, and powerful computing capabilities, transformed AR from a niche technology into one accessible to the general public (Billinghurst et al., 2015). These advancements made it

possible for everyday users to engage with AR through applications on their mobile devices, paving the way for AR's integration into fields such as education, retail, and entertainment.

The release of Pokémon GO in 2016 marked a turning point for AR's visibility in the mainstream consumer market. This mobile game utilized AR to overlay digital creatures onto real-world environments, bringing AR into the public consciousness in a way that had not been seen before. The game's success demonstrated AR's potential for wide-scale consumer adoption and highlighted the role that mobile devices could play in making AR a ubiquitous part of everyday life (Paavilainen et al., 2017).

As AR continues to evolve, its potential applications in education, including architectural education, have become increasingly evident. By leveraging the capabilities of mobile devices, AR can provide students with interactive, real-time visualizations, allowing them to engage with complex architectural concepts in a more intuitive and immersive way. This has opened up new possibilities for teaching and learning, especially in disciplines where spatial understanding is critical.

3.1.6 Integration of AR in Architectural Education

The integration of Augmented Reality (AR) into architectural education has progressed as educators recognized the potential of this technology to enhance learning experiences. AR offers a unique platform by overlaying digital information onto the physical environment, allowing students to visualize and interact with architectural models in real-time. This hands-on approach promotes spatial awareness and stimulates creative thinking and design exploration (Guntur et al., 2020).

Early applications of AR in architectural education were primarily experimental, focusing on enhancing specific aspects of the curriculum. For instance, Mo et al. (2014) conducted a study on the use of AR to teach architectural design principles and found

that AR improved students spatial cognitive abilities and pattern comprehension. The study concluded that students who used AR had a better understanding of spatial relationships and were more confident in applying design principles to complex architectural challenges compared to those using traditional methods.

Similarly, Martín-Gutiérrez et al. (2015) demonstrated that AR promotes collaborative and autonomous learning in higher education by providing interactive and immersive experiences that actively engage students in design exploration.

Their research identified three key attributes of AR that contribute to these educational benefits:

Real-time Interaction & Shared Environments – AR enables students to collaborate in real-time within the same digital space, allowing them to co-create, manipulate, and refine designs interactively. This shared environment fosters teamwork by ensuring that all group members can contribute meaningfully to a design discussion, improving communication and collective problem-solving.

Exploratory and Experiential Learning – Unlike static 2D representations, AR allows students to experiment with design variations dynamically, testing different spatial configurations and materials in real-time. This hands-on approach enhances autonomous learning, as students are encouraged to take initiative, explore solutions independently, and develop their design ideas without relying solely on instructor guidance.

Increased Engagement and Motivation – The immersive nature of AR has been shown to increase student motivation and engagement, making them more willing to collaborate and experiment with complex design challenges. The ability to visualize concepts

spatially encourages deeper cognitive processing, strengthening critical thinking and problem-solving skills.

As a result, Martín-Gutiérrez et al. (2015) argue that AR does not merely serve as a visualization tool but functions as an active learning environment that supports both collaborative teamwork and individual exploration, helping students develop the necessary skills for architectural practice.

However, the adoption of AR in architectural education faced several challenges. These included the high cost of AR-enabled devices, the need for technical proficiency, and the requirement for robust infrastructure to support AR applications. Despite these obstacles, early adopters recognized the transformative potential of AR and continued to experiment with its applications in design studios and other educational settings. The outcomes of these early trials indicated that while technical barriers existed, the educational benefits, such as increased student engagement, improved spatial understanding, and enhanced collaboration, were significant enough to justify further exploration (Mo et al., 2014; Martín-Gutiérrez et al., 2015).

3.1.7 Current Trends and Future Directions

As AR technology continues to evolve, its integration into architectural education has become more sophisticated and impactful, aligning with the broader pedagogical goal of enhancing students' learning experiences through immersive technologies. This section explores the current trends in AR integration within architectural education, connecting back to the overall research question: how can immersive technologies like AR and VR enhance student engagement, spatial understanding, and design outcomes? (Mo et al., 2014).

Recent studies have explored the use of AR to simulate real-world design challenges, provide experiential learning opportunities, and improve collaborative design processes

(Diao & Shih, 2019). For instance, Lai et al. (2024) investigated the application of AR in online teaching models and demonstrated its ability to facilitate experiential learning, improving both student engagement and interaction in a virtual environment. This research highlights the capacity of AR to bridge the gap between theoretical knowledge and practical application, a central theme in architectural education. By allowing students to interact with their designs in a more intuitive and immersive way, AR provides valuable insights into experiential aspects such as natural lighting, spatial proportions, and materiality (Mo et al., 2014).

Today, AR is increasingly recognized as a valuable tool for enhancing architectural education. Research has consistently shown that AR can significantly improve students' spatial understanding, problem-solving abilities, and overall engagement in the learning process (Guntur et al., 2020). Additionally, studies such as those conducted by Wu et al. (2013) have emphasized AR's ability to foster collaboration and teamwork, enabling students to work together in virtual spaces and share real-time feedback. This collaborative functionality is particularly valuable in architectural design studios, where teamwork and iterative feedback play crucial roles in the learning process.

As AR becomes more integrated into architectural curricula, educators are exploring innovative approaches to curriculum design and assessment. One of the key directions for future research is the long-term impact of AR on students' learning outcomes and professional development. Chemerys et al. (2021) suggest that further studies will likely focus on the development of customized AR tools specifically tailored for architectural education, offering solutions that align more closely with the specific needs of architectural students and educators.

By reflecting on these trends and future directions, this chapter aims to demonstrate how AR, alongside VR, can reshape the architectural education landscape. The technology's

potential to improve engagement, collaboration, and real-time interaction supports the overall research objective of integrating immersive technologies to enhance architectural learning outcomes (Diao & Shih, 2019; Guntur et al., 2020; Chemerys et al., 2021). The future of architectural education is poised for transformation, driven by immersive technologies like AR that foster more dynamic, collaborative, and experiential learning environments (Mo et al., 2014; Wu et al., 2013).

3.1.8 Early Interest towards VR and AR in Architectural Education

The integration of both Virtual Reality (VR) and Augmented Reality (AR) into architectural education began gaining traction in the early 2000s, with early adopters exploring their potential to enhance spatial understanding and design processes. VR, in particular, allowed for immersive visualization of architectural designs, enabling students to gain a deeper understanding of spatial relationships and design principles. Rather than replacing traditional design methods, VR functions as a complementary tool in an iterative learning cycle.

Typically, students begin by conceptualizing designs using conventional methods, such as hand sketches, physical models, or CAD software. They then translate these initial concepts into VR environments, where they can experience their designs at full scale, assess spatial relationships, and identify potential design flaws. This immersive feedback loop allows for real-time modifications, encouraging students to iterate on their designs based on what they observe in VR.

However, early adopters of VR faced significant challenges, including the high costs of hardware, limitations in software capabilities, and the need for extensive training to use the technology effectively. As the technology continues to evolve, addressing these barriers will be crucial to fully integrating VR into architectural education as an iterative,

exploratory design tool. In the early 2000s, VR was still relatively inaccessible for most educational institutions due to these barriers (Pimentel & Teixeira, 1995).

By the mid-2010s, technological advancements made VR more accessible for educational purposes. Platforms such as Oculus Rift and HTC Vive introduced high-resolution displays and intuitive controls, providing more realistic and engaging immersive experiences for students. This marked a turning point for VR in architectural education, as the technology became more practical and feasible to integrate into design studios and classrooms (Whyte & Nikolić, 2018). Despite this progress, gaps in the research remain regarding the best practices for integrating VR into curricula and how it impacts students' long-term design thinking and professional development (Huang et al., 2018). Identifying and addressing these gaps forms an essential part of ongoing research in immersive technologies for education.

Augmented Reality (AR) followed a similar trajectory, albeit with slightly different applications in the early stages of its development. Originally conceived for industrial and military applications, AR's use in architecture became more prominent as mobile computing and graphics processing technologies advanced in the late 2000s (Caudell & Mizell, 1992). AR's early promise lay in its ability to overlay digital information onto physical environments, which allowed students to engage with architectural models in real-time, offering new ways to visualize and manipulate designs. Initial applications of AR in architectural education were experimental, with educators testing its potential to improve spatial cognition and collaborative learning (Mo et al., 2014).

The integration of AR in design studios faced challenges similar to those encountered with VR—high costs, technical limitations, and the need for infrastructure that could support the technology. However, as AR became more affordable and widely accessible, its use in architectural education expanded, particularly in urban planning and

construction simulations, where it allowed students to see how their designs would function in real-world settings (Martín-Gutiérrez et al., 2015). Despite this, research into AR's long-term educational impact is still in its early stages, with limited studies on how AR can fully enhance pedagogical outcomes. Further exploration is needed to understand how AR can be seamlessly integrated into curricula, and how it influences students' spatial understanding and design creativity (Chemerys et al., 2021).

As technology continues to advance, both VR and AR are poised to play increasingly significant roles in shaping the future of architectural education. These technologies offer immersive, interactive, and engaging learning experiences that bridge the gap between theory and practice. However, the literature indicates gaps in understanding how best to implement these technologies, particularly regarding their long-term impact on student learning and professional development (Mo et al., 2014). Identifying these gaps helps justify the need for further research into how VR and AR can be optimally integrated into architectural education to maximize their benefits.

3.2 Sandbox Symbolism

3.2.1 LEGO

The primary aim of this PhD research is to examine the integration of VR and AR technologies into architectural education and evaluate their impact on enhancing creative design processes. This aim is supported by a set of research objectives and questions, which further investigate how immersive technologies influence spatial cognition, collaborative learning, and design iteration within architectural pedagogy. When examining creativity and design thinking, the process itself is often more critical than the final result (Rodrigo, 2010). However, in today's design culture, students and tutors may get caught up in surface-level aesthetics, or what Rattenbury (2005) describes

as a ‘wallpaper culture,’ which prioritizes visual appeal over deeper design thinking. This critique highlights a concern that architectural education risks becoming overly focused on aesthetics rather than meaningful problem-solving. Rather than simply contradicting this perspective, Lawson’s and Schön’s works (Lawson, 2006; Lawson, 2002; Schön & Wiggins, 1992; Schön, 2017) reframe the discussion by emphasizing that architects are not merely stylists but complex thinkers and problem solvers. Their research suggests that while aesthetics play a role in architecture, true design excellence emerges from an iterative, reflective process that integrates spatial, functional, and conceptual problem-solving. In this way, rather than being distracted by surface-level aesthetics, architects must engage with design challenges on multiple fronts, reinforcing the importance of design iteration, critical reflection, and deeper creative inquiry in architectural education.

LEGO serves as an effective metaphor to explain the architectural design process. Unlike toys that provide predefined moulds or fixed assembly instructions, LEGO offers children a systematic yet flexible medium for creative exploration. The key aspect here is that while LEGO imposes some constraints—such as the need for individual pieces to fit together according to a set system—it still allows for a great degree of creativity within these limits (Poon, 2018). This mirrors the ‘systematic sandbox’ approach in architecture, where the designer must work within the constraints of materials, structures, and codes, yet still has room for creativity and innovation (Daniela, 2018).

Moreover, LEGO employs an outside-in approach: children start by following visual instructions to assemble specific models. Once familiar with these steps, they begin experimenting with new, self-directed creations. This closely aligns with Schön’s concept of reflective practice, where students initially learn by observing or imitating their tutor’s work but eventually move toward developing their own unique solutions (Schön, 2017).

In both LEGO play and architectural education, students learn by doing—an approach that encourages applied learning through experimentation and iteration.

The key link between this metaphor and VR/AR technologies lies in the ability of these immersive tools to bring a similar ‘systematic sandbox’ approach into the architectural studio. VR and AR provide a more intuitive and natural platform for students to engage with their designs interactively, allowing them to “tinker” with spatial arrangements and experiment with architectural forms in real-time, much like children do with LEGO pieces (Turckes & Kahl, 2011). In this way, VR and AR encourage a learning-by-doing approach, where students can quickly prototype, test, and refine their designs in a virtual space, promoting a culture of critical collaboration and reframing failure as part of the creative process.

By allowing students to immerse themselves in virtual environments and manipulate digital architectural models in ways that traditional methods cannot, VR and AR offer new opportunities for creativity and design exploration in architectural education. These tools enable students to engage in reflective practice more dynamically, iterating on their designs in an immersive and interactive space that fosters experimentation and innovation. Therefore, the use of VR and AR in the studio environment could help replicate and enhance the creative, hands-on learning experience akin to playing with LEGO, providing students with the freedom to experiment while still working within the constraints of the architectural system.

3.2.2 Minecraft

It is not only in the physical world that the concept of learning through play has become an efficient means of expressing architectural creativity. In the virtual world, Minecraft stands as perhaps the most well-known example of a cyber-systematic sandbox, where players can build, explore, and create within a set of rules and virtual physics (French et

al., 2016). Like LEGO, Minecraft offers a platform for limitless creative possibilities; however, what sets it apart is that Minecraft allows users to inhabit and occupy the world they create from a first-person perspective, adding a new dimension of immersion and interaction that goes beyond physical toys like LEGO (Callaghan, 2015).

In Minecraft, players take on the role of both creator and inhabitant, directly interacting with their creations at a personal level (French et al., 2014). This experience offers an immersive toolkit of interactive objects, allowing users to shape not only the structures but also the environment around them. The game's design framework enables players to engage with a range of building blocks and tools to modify their virtual world in real-time. Unlike games like SimCity, where the player assumes the role of a detached "god-like" overseer, Minecraft gives users the agency to become creative creators, where they actively engage with and navigate the spaces they design (Lobo, 2008).

The accessibility of Minecraft across generations has made it a popular tool for fostering collaborative and creative exploration (Davidson & Lees, 2014). From young children building their first structures to more experienced players constructing intricate recreations of cities or functional in-game computers, Minecraft serves as a prime example of how an interactive and collaborative sandbox tool can turn design into play (French et al., 2016). The multiplayer aspect of Minecraft further enhances its value as a learning tool, as players collaboratively build and share knowledge, engaging in a form of virtual interactive learning (Callaghan, 2015).

Perhaps what makes Minecraft even more pertinent for this research is that, unlike LEGO, it operates in a virtual environment and allows for greater collaboration and interaction (French et al., 2016). Players build and inhabit their worlds in real-time, exploring and modifying their designs in an immersive setting. This virtual experience mirrors the

potential of VR design studios, where students can collaboratively create and interact with architectural models, learning by doing within a virtual space.

The relevance of Minecraft to VR and AR integration in architectural education is significant. We are now seeing a generation of people who are already accustomed to creating in virtual environments, which lowers the barrier for adopting immersive technologies in educational settings (Davidson & Lees, 2014). This familiarity with digital tools and virtual worlds opens the door for VR and AR, offering educators an opportunity to harness these technologies to further engage students and encourage creative exploration in architectural design studios. Minecraft has paved the way for VR and AR by developing a user base that is comfortable with inhabiting, interacting, and creating in virtual worlds, and this is a natural progression toward integrating these immersive technologies into architectural education (Chemerys et al., 2021).

3.2.3 Sandboxes in Architectural Education

This PhD explores the future of architectural pedagogy through the integration of VR and AR technologies. A comprehensive review of the literature on architectural pedagogy has highlighted the importance of reflective teaching and the emphasis on nurturing students' progress in learning how to design. These principles, when applied to VR and AR, open the door to exploring how the increased interactivity and the evolution of dimensional planes can transform architectural education.

As discussed earlier, LEGO and Minecraft serve as relatable sandbox environments where learning through play is a core component (Overby & Jones, 2015). In architectural education, especially in the design studio, there is a noticeable parallel to this learn-and-play relationship. Students often explore three-dimensional possibilities through concept models, while tutors sketch over drawings or demonstrate new approaches

using models in progress. These interactions are subtle examples of play and learn in action (Narayan, Chen, & Xie, 2019).

Even when playing Minecraft, players must consider aspects such as materials, layout, ease of access, illumination, terrain, and environment—much like in architectural design. Players often discuss these elements with friends or more experienced players within the communities they form, seeking feedback and ideas for improvement (Davidson & Lees, 2014). Similarly, in the design studio environment, students and tutors engage in collaborative discussions, offering feedback and solutions for design problems. The similarity between these two environments suggests that the design studio could potentially thrive in a virtual, cyber-world.

However, introducing VR and AR to architectural education raises important questions about design history and the evolution of ideas. In traditional design processes—using pen, paper, and models—there is a visible design history, where sketches, resketches, and models serve as a record of the design evolution. This history is crucial, especially when encountering a design dead-end, as students and tutors can return to earlier versions to explore different pathways.

In a VR/AR world, however, the history of design iterations could be easily erased or overlooked, as changes are made in real-time without an inherent physical record of past versions. This presents a potential challenge in architectural education and practice, where design evolution is crucial for reflection and iterative learning. However, this risk can be mitigated through structured workflow development and digital version control systems. Many VR/AR platforms now integrate automatic version tracking, cloud-based backups, and design history logs, enabling students and professionals to document changes, compare iterations, and revert to previous stages if needed. By incorporating

best practices for saving, archiving, and reviewing design iterations, immersive technologies can not only preserve design evolution but also enhance reflective learning through interactive, time-stamped design tracking. While document versioning is common in written work, how do we ensure that design history is preserved in a VR/AR environment? One possible solution could involve automated tracking of changes in virtual environments, similar to the way document versioning works in word processors. Such a system could save different iterations of a design, allowing students to return to earlier stages if needed. This would help maintain a clear record of the evolution of their creative process (Turckes & Kahl, 2011).

Moreover, the question of authorship and originality becomes more complex in a VR/AR environment. In traditional settings, it is easy to distinguish between the tutor's contributions and the student's work based on individual sketch styles or model-making techniques. However, in a virtual environment, where interactions and changes are seamless, how do we ensure that the final design is genuinely the student's work and not overly influenced by the tutor? To address this, VR/AR platforms could include trackable features that allow users to see who made specific changes to a design, thereby ensuring clarity in authorship and maintaining academic integrity (Overby & Jones, 2015).

In conclusion, while VR and AR offer immense potential for enhancing creativity and collaboration in architectural education, careful consideration must be given to preserving design history and ensuring authenticity in the creative process. Solutions such as automated versioning and tracked interactions could be crucial for integrating these technologies into the architectural studio, ensuring that both the process and the outcome of design remain transparent and reflective of the student's individual creativity.

3.3 The Human in Design

Before discussing research and methods regarding VR in contemporary fields, this report introduces a standard approach to research in Digital Architecture. The following paragraphs categorize research into two groups: the empirical approach and the natural 'human' approach. These terms are used to distinguish research that views VR/AR as design tools and research that treats these technologies as platforms for creative thinking. Current research concerning VR and AR falls under the broader field of Digital Architecture, and it is crucial for this PhD to explore the roots of research methodologies in this field to develop a robust approach.

Cross (1999) provides an intensive summary of methods used in digital architecture research, which include interviews with designers (Cross, 1999; Lawson, 1994), observations and case studies (Achten, 2003), and reflection and theorizing (Schön, 1987; Simon, 1981). These methods fall under the 'human' approach, focusing on the thinking process of design, as opposed to the empirical aspects such as communication, visualization, or efficiency. Most of these methods were used to study the planning ability of designers and to gather their reflections on the processes they employ (Cross, 1999). Schön's (1987) work in the studio context framed patterns of 'doing and coaching' as models for teaching artistry, which continues to influence contemporary studio environments. Here, students learn through 'learning by doing,' experimenting with conceptual issues while making unexpected discoveries (Tversky, 2001; Do & Cross, 1999).

When computers first entered the architectural design process, they were seen merely as tools for drafting and modelling (Andia, 2002). However, as computers evolved to support analysis and simulation, they were soon recognized as 'intelligent assistants' capable of augmenting designers' decision-making by automating trivial tasks (Terzidis, 2006, p. 60). Today, with greatly advanced computing power, software tools, and simulation capabilities, computers are deeply integrated into the architectural design studio. Nevertheless, early scepticism toward digital

tools—particularly concerns that computers’ cold, fabricated nature could diminish the human element of design—persisted in architectural discourse in the late 20th and early 21st centuries (Madrazo, 2000; Hanna & Barber, 2001). However, given the rapid evolution of computational design, parametric modeling, and immersive technologies, these concerns have evolved rather than disappeared. Contemporary debates focus less on whether digital tools diminish creativity and more on how they reshape design thinking, workflow integration, and pedagogical approaches (Oxman, 2017; Celani & Vaz, 2022). While some educators remain cautious about over-reliance on automation, emerging research demonstrates that VR, AR, and AI-driven generative design can enhance creative exploration rather than replace human intuition. Thus, while early critiques still echo in architectural pedagogy, the discourse has shifted toward finding a balance between computational efficiency and human-driven creativity, making it crucial to reassess the role of immersive technologies in architectural education.

CAAD (Computer-Aided Architectural Design) tools have become central to architectural education. While CAAD’s ability to simulate complex building behaviours and automate processes is a tremendous asset, some educators argue that it can detract from the fluid dialogue and creative discussions often found in more traditional design methods involving pen and tracing paper (ATA, 2021). Early perceptions of CAAD echoed concerns about human essence being lost in architectural design (Kalay, 2004), with some fearing that CAAD could replace rather than complement human creativity (Kotata & Zierke, 2021). This notion is crucial in understanding the current challenges posed by VR and AR technologies in the design studio.

VR/AR technologies are now at a similar crossroads to early CAAD. Researchers such as Mathysen & Glorieux (2021) have found that, although VR offers immense potential, the lack of user-friendly, interactive design software can discourage researchers from exploring its full capabilities beyond visualization. Their study used case studies and user feedback analysis to propose improvements to VR interfaces, arguing that intuitive software is critical for encouraging

designers to adopt VR as more than just a visualization tool. This research serves as a foundational method for exploring similar studies in VR and AR applications within architectural pedagogy, which will be further discussed in later chapters.

As noted by Janssen et al. (2002), computers in architectural design now serve as tools for drafting, modelling, simulation, and the manipulation of complex parametric forms. This shift from basic CAD systems to complex, interactive platforms signifies that these tools have already become integral components at the centre of the design process, not merely tools of the future.

In casual discussions with architectural practitioners and tutors (based on personal experience during preliminary VR demonstrations), there appears to be similar scepticism regarding VR/AR, particularly about how these tools could fit into the expressive, creative dialogues of the design studio. Much like early CAAD, the concern is that VR/AR could disrupt the natural flow of conversation during design reviews or that it might replace more tactile, intuitive methods of interaction with abstract, digital ones (Terzidis, 2006). However, CAAD's eventual integration into architectural studios shows that technology can evolve from scepticism to a core component of the design process.

It is likely that VR and AR will follow a similar trajectory to CAAD, moving from tools initially seen as cold and detached to central platforms for interactive design reviews and immersive design experiences. To fully integrate VR and AR into architectural pedagogy, it will be essential to address both technical limitations and user scepticism, ensuring these tools complement, rather than replace, the human cognitive processes that drive architectural creativity.

3.4 Research Limitations

The integration of VR and AR technologies in architectural education has faced significant limitations, particularly regarding user expertise and training, as well as challenges related to programming and software interface design. Historically, the adaptation and application of any

computer- or digitally-based technology in architecture has been met with obstacles, largely due to the technical expertise required and the steep learning curve for both students and educators.

The key challenge in overcoming user training limitations lies in the development of clear, systematic tutorials, inductions, and instruction manuals. This is a standard practice in introducing new technologies, as structured learning systems have been shown to help users adapt more efficiently to new tools and platforms (Gabriska & Ölvecký, 2018). In modern contexts, the increasing availability of intuitive software has alleviated some of the pressures on users. However, the quality and depth of these learning systems are essential to ensure that both students and educators can fully leverage the potential of immersive technologies in architectural education.

The most crucial limitation in integrating VR/AR into architectural pedagogy relates to programming and interface design. Early research, especially in the 1990s and 2000s, highlighted that many VR systems required high levels of programming knowledge and were often developed in-house, meaning that only institutions with sufficient financial resources and technical expertise could adopt them (Ansar & Khan, 2016; Spiridonidis & Voyatzaki, 2007). This historical context helps explain why early VR and AR systems had limited applicability, as they demanded not only expensive hardware but also the ability to program and customize software for specific educational needs (Carver et al., 2021).

In the current state of play, many of these challenges have been addressed by the development of user-friendly platforms like Unity and Unreal Engine, which offer more accessible programming interfaces and tools for non-experts. Additionally, affordable VR/AR hardware such as the Oculus Rift and Microsoft HoloLens has made these technologies more attainable for a wider range of educational institutions (Gabriska & Ölvecký, 2018). However, there remain gaps

in terms of customization and integration into specific architectural curricula, as many off-the-shelf solutions still do not fully align with the pedagogical needs of architectural education.

The historical development of VR/AR research and application demonstrates that early adoption was severely limited by high costs and the requirement for specialized programming knowledge. This constrained the ability of many architectural schools to integrate these technologies into their curricula. Over time, advances in both hardware and software have addressed many of these barriers, but challenges remain, particularly in terms of customization and curriculum alignment. Moving forward, there is a need for further research and development in tailoring immersive technologies to the specific pedagogical frameworks of architectural education, ensuring that they can support both creative design processes and practical training (Spiridonidis & Voyatzaki, 2007).

3.4.1 Game Engines

In considering the development of VR and AR tools for architectural education, the question of whether to create custom software or adapt existing tools is central. The complexities of devising new software from scratch, especially in terms of the time and programming expertise required, make this approach less feasible (Mourkoussis et al., 2007). However, existing software, such as Gravity Sketch, presents a viable alternative for achieving many of the research aims related to immersive design environments (Buchanan et al., 2013). While the focus of the research may not be on software development per se, understanding the tools available is crucial for determining the best approach to integrate VR and AR into architectural pedagogy (Ansar & Khan, 2016).

Gravity Sketch is part of a new generation of VR design tools that offer professional-level design capabilities. Unlike earlier VR applications such as Tilt Brush, which focused more on artistic expression (Janssen et al., 2021), Gravity Sketch is designed with practical CAD (Computer-Aided Design) functionality in mind, making it suitable for architectural

design (Fricker et al., 2013). Recent features, such as co-creation—a collaborative design feature developed in partnership with Ford Motor Company—enable multiple users to work on a project simultaneously from different locations (Gabriska & Ölvecký, 2018). This functionality provides significant potential for architectural education, where collaboration and iterative design are key components of the learning process (Oxman, 2008). Additionally, VR/AR technologies contribute to accessibility by reducing geographical and logistical barriers, allowing students and educators to collaborate remotely in shared virtual environments. This is particularly beneficial in scenarios where physical studio access is limited, international collaboration is needed, or students with mobility restrictions require alternative learning solutions. By enabling real-time design modifications, shared virtual workspaces, and interactive feedback, immersive technologies enhance both collaborative engagement and accessibility, ensuring that more students can actively participate in design education regardless of their location or physical constraints. Other tools like Masterpiece VR and Medium are more focused on sculptural and organic designs, making them useful for other forms of creative exploration, though less relevant for CAD-specific needs in architecture (Huang et al., 2018).

In addition to standalone software like Gravity Sketch, game engines such as Unreal Engine and Unity could also be considered for this research. These engines are not typically used as design tools, but rather for creating interactive environments and simulations (Wang, 2009). However, they provide robust development platforms with extensive libraries of templates that can be adapted for various VR and AR applications. The flexibility of game engines allows for the creation of custom software with more specialized functionality if the current VR tools do not fully meet the research requirements (Kato, 2012). Both Unity and Unreal Engine have been widely used in

architectural visualization, making them valuable resources for further exploration (Azuma, 1997).

The decision to use existing off-the-shelf tools like Gravity Sketch or more customizable platforms like Unity will depend on the specific needs of the research and the desired outcomes. While off-the-shelf software may offer immediate functionality, game engines provide greater flexibility for modification and expansion, allowing for the creation of specialized design tools that could better support immersive education (Chemerys et al., 2021).

3.4.2 VR & AR User Experience

The user experience of Virtual Reality (VR) and Augmented Reality (AR) in architectural education has been a subject of increasing interest in the academic community. While both technologies offer immersive and interactive environments, their limitations pose distinct challenges for integration into educational settings. VR, characterized by its immersive nature, allows users to fully engage with virtual environments, creating an isolated experience that can facilitate deep focus on design but may hinder collaboration and interaction with the physical world (Guntur et al., 2020). The isolation caused by VR headsets can be a barrier to collaborative learning, a key component of architectural pedagogy, where peer-to-peer and tutor-student interactions are essential to the design process (Buchanan et al., 2013).

Recent studies have explored how modern VR systems, such as the HTC Vive, address some of these challenges. For instance, the inclusion of external cameras allows users to project real-world surroundings onto their virtual experience, offering some degree of spatial awareness that mitigates the complete isolation (Huang et al., 2018). However, VR still requires users to become familiar with the interface and navigation, which can

vary widely based on users' prior knowledge and technical skills (Martín-Gutiérrez et al., 2015). The learning curve associated with mastering these systems is significant, particularly for tutors and students with little experience in using immersive technologies (Ansar & Khan, 2016).

AR, on the other hand, offers a different set of challenges. While it enables users to overlay digital information onto the physical environment, fostering an interactive and collaborative experience, it often requires complex installations or expensive gear that limits widespread use in education (Azuma, 1997). Nevertheless, AR social and instructional nature makes it particularly well-suited for teaching technical aspects of architectural education, such as structural behavior or material performance (Diao & Shih, 2019). AR has been employed in other fields such as flight simulation and medical training, where it is used to simulate complex scenarios, providing students with hands-on experience in controlled environments (Belcher & Johnson, 2008). These applications suggest that AR could be integrated into architectural education both within the design studio and as a supporting tool in satellite courses (Oxman, 2008). Within the studio environment, AR enhances spatial visualization, real-time design iteration, and interactive critique, allowing students to experience architectural forms at scale and simulate material or structural performance dynamically. This bridges the gap between conceptual design and real-world application, reinforcing the core principles of studio-based learning. At the same time, AR also serves as a valuable tool for satellite content, such as structural analysis, environmental simulations, or historical architectural studies, where interactive overlays can enhance understanding beyond traditional 2D representations. Its ability to visualize architectural failures and test design principles under realistic conditions makes it particularly effective for both hands-on studio learning and theoretical coursework, expanding its role within architectural education.

Studies have shown that AR and VR can complement one another in architectural pedagogy by addressing different aspects of the learning process (Chemerys et al., 2021). While VR is ideal for creating immersive environments that allow students to explore and interact with virtual architectural models, AR can be used to enhance real-world interactions, providing real-time feedback and fostering collaboration. For example, Gravity Sketch—a popular VR and AR design tool—has been used to enable remote collaboration in design processes, allowing multiple users to co-create architectural models in real-time (Paavilainen et al., 2017). This type of remote collaboration aligns with the pedagogical needs of design studios, where feedback and iterative development are crucial (Wang, 2009).

The use of AR in architectural education has also been highlighted as a tool for enhancing design discussions by overlaying digital models onto physical blueprints or construction sites, thus providing students with a more tangible connection to their projects (Guntur et al., 2020). While early adoption of AR in education was hindered by high costs and limited hardware availability (Belcher & Johnson, 2008), recent advancements have made AR more accessible. The proliferation of mobile AR applications, affordable AR-enabled devices, and web-based AR platforms has lowered some financial and technical barriers, allowing broader integration into architectural education (Birt et al., 2021; Dunston & Wang, 2020). However, institution-wide adoption remains inconsistent, particularly in underfunded institutions or regions where access to high-performance AR devices is still cost-prohibitive. Additionally, the challenge of developing standardized pedagogical approaches for AR integration continues to limit its full potential in design education (Celani & Vaz, 2022).

In summary, while both VR and AR hold great potential for revolutionizing architectural education, their adoption is not without challenges. . To fully harness the potential of VR

and AR in educational settings, it is essential to address key challenges, including user isolation from the real environment in VR, the technical expertise required to operate both technologies, and the cost and limited availability of AR devices. Research suggests that continued experimentation with these technologies could lead to significant improvements in student engagement, spatial understanding, and collaborative learning (Diao & Shih, 2019). Future studies will need to focus on developing user-friendly interfaces and affordable solutions to ensure that these technologies are accessible to a broader range of students and educational institutions (Buchanan et al., 2013).

3.4.3 Harmonised MR

Mixed Reality (MR) represents the convergence of Augmented Reality (AR) and Virtual Reality (VR), creating immersive environments where physical and digital elements interact in real time (Speicher et al., 2019). MR offers unique opportunities in architectural education, enhancing learning experiences by providing dynamic, interactive, and contextually rich environments (Kairu, 2021). Contemporary research highlights its transformative potential in altering traditional teaching methods and bridging the gap between theoretical concepts and practical application (Liu et al., 2020).

One significant advantage of MR in architectural education is its ability to facilitate a deeper understanding of spatial relationships and design principles. Wang et al. (2018) found that MR environments significantly improve students' spatial cognition by enabling them to interact with three-dimensional models in both virtual and physical spaces. This ability to merge real-world context with digital models provides a more intuitive grasp of spatial dynamics, referring to the relationships between architectural elements, spatial proportions, and the way users experience movement within a space. By visualizing scale, depth, and spatial hierarchy in real time, AR and VR enable students to interact with architectural designs from multiple perspectives, improving their ability to assess

circulation patterns, spatial flow, and the functional organization of built environments. This immersive approach enhances their comprehension of how spaces are perceived, navigated, and experienced in three dimensions.

Another critical feature of MR is its support for collaborative learning. Gül and Gu (2019) demonstrated that MR platforms allow students and instructors to interact in a shared virtual space, regardless of their physical locations. This real-time collaboration enables more interactive and engaging design discussions and critiques, further enhancing design iteration and feedback mechanisms. This fosters a richer, more inclusive learning experience that emphasizes participation and shared knowledge creation.

MR also contributes to experiential learning by blending real-world elements with digital information, allowing students to visualize their designs within their intended physical context (Azhar & Kouider, 2021). For example, Liu et al. (2020) found that MR enables students to experience and evaluate their architectural designs more realistically, providing immediate visual feedback. This leads to enhanced creativity and problem-solving skills, as students can rapidly iterate their designs based on real-time feedback and visual interactions.

In addition to enhancing visualization and collaboration, MR addresses some of the limitations posed by using VR or AR in isolation. While VR can be isolating and AR may lack full immersion, MR provides a balanced approach that leverages the strengths of both technologies (Speicher et al., 2019). By allowing users to interact with both digital and physical elements simultaneously, MR can support a more comprehensive and engaging learning experience (Kairu, 2021).

Ultimately, MR offers a holistic educational tool for architectural education, seamlessly integrating into existing curricula and providing opportunities for innovative teaching methods (Azhar & Kouider, 2021). Its ability to combine the immersive qualities of VR with

the contextual relevance of AR makes it particularly effective in helping students connect theory with practice. As MR technologies continue to evolve, their role in transforming architectural education is expected to grow, offering students richer, more interactive experiences that foster creativity, collaboration, and critical thinking.

3.4.4 Health Related Limitations

A significant concern in the integration of Virtual Reality (VR) into architectural education is the potential health effects on users. Although VR offers immersive learning experiences, recent studies have highlighted the risk of musculoskeletal strain and discomfort due to prolonged or repetitive interactions with VR environments. Jay Kim from Oregon State University's College of Public Health and Human Sciences led research evaluating how common VR movements—such as reaching and interacting with distant virtual objects—contribute to muscle strain and physical fatigue (Kim et al., 2021). The study emphasizes the lack of formal standards and guidelines for VR interactions, which poses potential risks for long-term users in educational and industrial settings.

In comparison to conventional computer use, where users are often supported by a desk or armrests, VR users must engage in full-body movements without the same ergonomic support, creating the potential for overexertion and discomfort (Kim et al., 2021). Additionally, the immersion in a virtual environment leaves the user temporarily disconnected from the physical world, increasing the likelihood of postural strain and accidental collisions with physical objects (Nahar et al., 2020). These issues may be more pronounced in architectural education, where students are expected to spend extended periods interacting with complex 3D models.

Another health-related limitation of VR is the phenomenon of cybersickness, where users experience symptoms similar to motion sickness, including dizziness, nausea, and

disorientation after prolonged use of VR headsets (LaViola, 2000). Cybersickness has been shown to affect a significant portion of VR users, particularly during the first interactions with the technology (Kennedy et al., 2010). This presents challenges in educational settings where prolonged engagement with immersive environments is needed for design iteration and spatial analysis.

While these health concerns are significant, it is important to note that ongoing advancements in VR hardware, such as improved tracking systems, lighter headsets, and the incorporation of ergonomic design principles, are helping to mitigate these risks (Coles et al., 2018). Nonetheless, further research is required to establish clear guidelines for the safe and sustainable use of VR in architectural education.

3.5 Contemporary VR/AR Research Methods Across Disciplines

A close examination of contemporary VR/AR research methods reveals patterns that can inform a referable standard for this research. These studies, primarily empirical, provide guidelines on how VR/AR learning environments function across multiple disciplines, highlighting both potential benefits and limitations.

Chen (2012) acknowledged VR as a promising learning tool, yet pointed out key challenges such as the need for suitable learning theories or models to formalize VR's incorporation into educational practices. This underscores the importance of not just adopting VR for its novelty, but integrating it into pedagogical frameworks to optimize its educational value.

Similarly, Mikropoulos and Bellou (2006) explored the pedagogical value of VR, identifying several critical features that make it uniquely suited for educational purposes:

3D spatial representation – The ability to represent spaces in three dimensions helps users understand complex spatial relationships.

Multisensory interaction – Engaging multiple senses enhances the immersive experience and aids cognitive retention.

Immersion – Deep engagement in the virtual world fosters greater concentration on the task.

Real-time manipulation – The ability to intuitively interact with objects in real time makes VR a dynamic learning tool.

Building on this, Mikropoulos and Natsis (2011) proposed seven technological characteristics of VR that contribute positively to learning outcomes:

First-order experiences – VR provides direct, firsthand experiences rather than abstracted, second-order representations.

Natural semantics – The interactions in VR mirror real-world actions, making them easier to understand.

Size – VR allows the manipulation of scale, enabling learners to perceive objects in both macro and micro perspectives.

Transduction – The transformation of one form of information into another, enhancing the understanding of complex data.

Reification – The visualization of abstract concepts as tangible objects in VR.

Autonomy – The learner can explore the environment independently, fostering self-directed learning.

Presence – The sensation of 'being there,' which can increase engagement and retention.

These features support several learning affordances, such as:

Spatial knowledge representation: Enhancing students' ability to visualize and manipulate spatial information.

Experiential learning: Allowing students to 'learn by doing' in a virtual context.

Engagement: Increasing learner involvement through immersive experiences.

Contextual learning: Providing relevant, real-world applications in the virtual environment.

Collaborative learning: Enabling real-time cooperation and discussion among users in shared virtual spaces (Mikropoulos and Natsis, 2011).

The relevance of these characteristics to architectural education is evident, as VR and AR provide students with firsthand experiences in exploring complex structures and spatial relationships, which are fundamental to architectural learning. However, as S.H. Kim et al. (2012) emphasized, while these technologies promise enhanced engagement and learning, there remains a lack of practical guidance on how to effectively integrate VR into existing educational systems.

Although challenges such as cost, accessibility, and best practices for curriculum integration are expected hurdles when introducing new technologies in education, the most critical factor for successful implementation is structured training for both students and educators. Without proper training, the potential benefits of VR—such as enhanced engagement, spatial understanding, and real-time collaboration—may not be fully realized. Therefore, this research highlights technical training initiatives as a core component of best practices, ensuring that stakeholders are equipped with the necessary skills to fully utilize VR within architectural curricula.

By prioritizing educator training and student onboarding, institutions can mitigate many of the initial adoption barriers and establish a sustainable framework for immersive technology integration in architectural education.

In terms of application, Fernandez (2017) proposed a structured six-step methodology for the adoption of VR/AR in education:

1. Training educators: Ensuring that teachers are familiar with the technology and its pedagogical uses.
2. Developing prototypes: Creating conceptual models that illustrate the potential uses of VR/AR.
3. Teamwork: Collaborating with a technical programmer and an educational architect to develop robust systems.
4. Production: Designing the actual educational experience.
5. Implementation: Teachers using these solutions within their subjects.
6. Evaluation: Assessing the experience with students and adjusting as needed.

This systematic approach offers a roadmap for integrating VR/AR into education, but as Dalgarno and Lee (2010) pointed out, more research is needed to bridge the gap between the theoretical potential of VR and its practical application in educational settings.

Conclusion: The research methods and findings discussed here provide a strong foundation for understanding how VR/AR can be leveraged in architectural education. However, there is still a need for more practical and empirical studies that focus on the implementation and assessment of these technologies in real-world educational environments. As this PhD research moves forward, these insights will guide the development of VR/AR integration methods that are grounded in both technological potential and pedagogical effectiveness.

3.5.1 Healthcare

Healthcare has emerged as a leading sector for VR/AR implementation, as identified in the survey by Durrani and Pita (2018), which reviewed 38 academic papers. Their analysis revealed that 12 out of 38 papers focused on healthcare, making it the most prominent subject area for VR/AR application. The survey indicated that all the studies produced consistent positive learning outcomes, showcasing the effectiveness of immersive technologies in medical education and training.

In most of these studies, researchers or evaluators developed their own VR/AR applications to suit specific training needs (11 out of 12 papers), while only one study utilized a commercially available application. For example, Davis et al. (2016) demonstrated the successful use of the VIPER (Virtual Interactive Presence and Augmented Reality) iPad-based tool developed by Shenai and Dillavou (2011). VIPER allowed neurosurgeons to provide long-distance virtual assistance via wireless internet, effectively increasing global neurosurgical capacity by offering a scalable, cost-effective platform for remote training and guidance (Davis et al., 2017).

Other notable healthcare applications of VR/AR included training in anatomic pathology education, autism treatment, laparoscopic assistance, radiotherapy, and general health science education. The positive outcomes from these studies demonstrate VR/AR's capacity to improve both technical skills and decision-making in medical contexts.

In addition to healthcare, engineering also demonstrated notable applications of VR/AR. Vieira and Seshadri (2017), for instance, developed a VR model for a charcoal mini-blast furnace (CMBF) to simulate green ironmaking processes. This virtual system, which incorporated commercial VR software, immersive drivers, 3D projectors, and other components, was successfully used to train workers, technical personnel, students, and equipment manufacturers, ultimately enhancing learning techniques concerning design operations and process control (Vieira et al., 2017).

While healthcare and engineering remain prominent fields of VR/AR research, applications also extend into areas like electrical power transformation operations and architectural model validation (Barata et al., 2015). Across these disciplines, the studies reported overwhelmingly positive results, highlighting the potential of VR/AR to revolutionize training and education.

3.5.2 Engineering

Engineering education has increasingly embraced VR and AR technologies to enhance learning experiences and improve student engagement. These immersive technologies offer unique opportunities for students to visualize complex engineering concepts, conduct virtual experiments, and interact with simulated environments. VR and AR have been utilized to create virtual laboratories where students can perform experiments and manipulate virtual objects (Hungler et al., 2019; Cecil et al., 2013). This approach is particularly beneficial in fields such as mechanical and electrical engineering, where hands-on experience with equipment and systems is crucial. Virtual laboratories allow students to conduct experiments without the need for physical lab space or expensive equipment. For instance, virtual reality can simulate hazardous environments or intricate machinery, enabling students to practice and understand safety protocols and operational procedures without the associated risks (Buchanan et al., 2013).

In research conducted by Glyn Lawson and colleagues, VR was employed to simulate hazardous work environments for engineering students, providing a safe space to practice safety protocols and emergency procedures (Lawson et al., 2010). This research demonstrated that VR could effectively prepare students for real-world engineering challenges, emphasizing the importance of hands-on learning in a risk-free environment.

AR applications in engineering education often overlay digital information on real-world objects, helping students to better understand spatial relationships and mechanical functions. For example, AR can project a 3D model of an engine over a physical engine, highlighting components and demonstrating how they interact (Akil et al., 2020). This immersive visualization aids in comprehending complex mechanical processes and enhances spatial reasoning skills, which are critical in engineering design and analysis (Chryssolouris et al., 2000).

AR's potential to enhance spatial understanding has been further explored in the work of Gary Priestnall, who examined the application of AR in geospatial education. By overlaying 3D models onto physical environments, Priestnall's research demonstrated the educational benefits of AR in helping students visualize and interact with complex spatial data (Priestnall, 2015).

VR and AR technologies also facilitate remote learning and collaboration among engineering students. Through virtual environments, students from different locations can work together on projects, share ideas, and solve problems collaboratively (Alizadehsalehi et al., 2019). This capability is particularly important in globalized engineering education, where cross-institutional and international collaborations are common. Additionally, remote laboratories equipped with AR can provide access to practical experiences for students who are unable to attend in-person sessions, ensuring equitable learning opportunities (Pantelidis, 2009).

3.5.3 Social Sciences

The social sciences have seen a growing interest in the use of VR and AR technologies to study and understand human behavior, social interactions, and cultural phenomena. These technologies offer novel approaches for conducting experiments, gathering data, and presenting findings. VR, in particular, provides controlled environments for experimental studies, allowing researchers to simulate real-world settings and study human behavior under controlled yet realistic conditions. For example, VR has been utilized to examine social anxiety by placing participants in virtual social scenarios, measuring physiological and psychological responses with greater control over experimental variables and environments, thereby leading to more reliable data and insights (Freeman et al., 2017).

Gary Priestnall's work at the University of Nottingham is a notable example in this field. His research explores the use of AR for understanding spatial relationships and cultural phenomena through the visualization of geographical data in augmented physical environments. This is particularly useful in geography, social sciences, and heritage studies, where AR overlays digital information onto real-world locations, allowing students and researchers to visualize the physical, historical, and social dimensions of a space (Priestnall, 2014). Priestnall's work on AR has also enhanced fieldwork experiences by providing interactive and immersive tools to better understand geographical and social data in their real-world context.

In social sciences, AR is increasingly used to bring historical and cultural sites to life. By overlaying digital reconstructions over physical ruins, AR provides an immersive historical experience that supports education and the preservation of cultural heritage (Marto & Gonçalves, 2019; Ramtohul & Khedo, 2019). AR has also been employed in social psychology to study social interactions by augmenting real-world settings with digital avatars and cues, facilitating deeper research into communication and group dynamics (Tost et al., 2019).

Both VR and AR have been integrated into educational contexts, particularly for training social science students in qualitative research methods and data analysis. In some instances, VR has been employed to simulate fieldwork environments, allowing students to practice ethnographic research techniques in a controlled setting (Montagud et al., 2022). Similarly, AR has been used to overlay data visualization tools onto physical spaces, helping students better understand spatial relationships and demographic data in urban studies (Parsons & Cobb, 2014). Priestnall's research also reflects these developments, as his AR-based approaches aid students in exploring spatial and

environmental data through interactive digital overlays on real-world settings, facilitating a hands-on approach to learning.

In the context of design education, such applications are significant. The ability to visualize data and spaces using AR enhances the learning process by making abstract concepts tangible. For example, AR's ability to overlay architectural or design models onto physical environments allows design students to visualize a proposed building on an actual site before construction begins. Using AR applications, students can place digital models within real-world contexts, assess how their designs interact with surrounding structures, lighting conditions, and pedestrian movement, and make real-time adjustments based on spatial constraints and functional considerations.

For instance, an architecture student designing an urban pavilion can use AR to overlay their 3D model onto an existing city plaza, enabling them to evaluate scale, accessibility, and how the structure integrates with the surrounding environment. This real-time, immersive feedback fosters experiential learning and helps students refine their designs to better align with real-world conditions. As design education becomes more interdisciplinary, tools like AR can bridge the gap between social sciences and architecture by enhancing the comprehension of spatial and social dynamics in urban settings, which are often central to both fields.

3.6 Focus on the Architectural Education

Research on contemporary experiments with VR in architectural education suggests that these technologies offer significant benefits for teaching and learning in design studios. VR enables students to immerse themselves in virtual models of their designs, providing a spatial understanding that is difficult to achieve through traditional methods (Zikic et al., 2020). By allowing users to experience a design from a first-person perspective, VR encourages deeper

interaction with the architectural space, which enhances comprehension of scale, proportion, and materiality.

AR has also been increasingly adopted in architectural education, providing tools that overlay digital information onto physical models or environments (Riera et al., 2019). This combination of digital and physical elements helps bridge the gap between design processes, offering real-time, contextual feedback on a student's work. In doing so, AR fosters an interactive learning environment that promotes experimentation and collaboration, making it a valuable addition to the architectural curriculum.

As these immersive technologies continue to evolve, they present opportunities to shift architectural pedagogy from traditional, static teaching methods to more dynamic, interactive models. Educators can leverage AR and VR not only for visualization and spatial comprehension but also for engaging students in participatory design processes that mirror real-world architectural practice (Buchanan et al., 2013). These shifts indicate that VR and AR will likely become indispensable tools in the architectural design studio of the future.

3.6.1 Collaborative Learning with VR

VR is particularly effective in the conceptual stages of design, where students can explore and iterate on their ideas in an immersive environment. Studies have shown that VR helps students better understand spatial relationships, proportions, and the impact of their design decisions on the overall aesthetic and functionality of a space. For example, Angulo et al. (2015) and Dorta et al. (2016) highlighted how VR allows for detailed walkthroughs of architectural models, enabling students to experience their designs as if they were built, fostering deeper engagement and creativity.

One of the significant advantages of VR in architectural education is its potential to enhance collaborative learning. Virtual environments can simulate real-world studio settings where students and instructors interact, critique designs, and discuss concepts in real-time. One of the significant advantages of VR in architectural education is its potential to enhance collaborative learning. Virtual environments can simulate real-world studio settings, where students and instructors interact, critique designs, and discuss concepts in real-time. This virtual collaboration closely mirrors professional architectural practice, where design teams frequently collaborate remotely using digital tools, cloud-based workflows, and Building Information Modeling (BIM) platforms. In professional settings, architects, engineers, and clients often work together across different locations, reviewing 3D models and providing real-time feedback through collaborative design software such as Revit, Rhino, or VR-enabled BIM platforms. By engaging in VR-based design collaboration, students develop key industry skills, including effective communication, remote teamwork, and iterative problem-solving. These skills are essential in modern architectural practice, where multidisciplinary teams must coordinate efficiently, navigate complex design constraints, and present ideas clearly to stakeholders. Thus, integrating VR into architectural education not only enhances student engagement but also prepares them for the digital and collaborative nature of contemporary architectural workflows.

Bartosh and Anzalone (2019) demonstrated how VR facilitated a collaborative design process, allowing students to work together on complex projects and learn from each other's insights and feedback. In their study, they compared the VR-based collaborative process to traditional in-person studio interactions. The results indicated that VR enhanced the quality of feedback and increased students' understanding of complex spatial relationships, while also fostering greater engagement among peers. However, it

was noted that the success of VR in fostering collaboration was highly dependent on the user's familiarity with the technology and the design software being used.

3.6.2 VR Integration with CAAD Design Software

Modern VR platforms integrate seamlessly with design software such as Autodesk Revit and Rhino, allowing students to import their models directly into VR environments. This integration streamlines the workflow, making it easier for students to move from 2D drawings to immersive 3D experiences. By visualizing their designs in VR, students can identify and resolve design issues early in the process, enhancing the overall quality and feasibility of their projects (Redondo et al., 2013).

Previous research often treats VR as a conceptual design tool, exploring various methods for using VR in an academic environment. For example, Angulo et al. (2015) and Dorta et al. (2016) explored VR as a design tool in the later stages of the design process, focusing on the exportation of models into VR. This approach was due to the lack of interactive platforms and the challenges of learning programming and incorporating it into existing software.

However, recent studies, such as Bartosh and Anzalone (2019), have shown that integrating VR with CAAD software has evolved significantly. Students can now interact with their models in real time within a fully immersive 3D space, enabling a more thorough design analysis and problem-solving approach. Unlike traditional screen-based walk-throughs, which provide limited spatial perception and rely on static viewpoints, immersive VR environments allow users to navigate freely, experience depth perception, and engage with designs at a 1:1 scale. Studies comparing fully interactive VR with screen-based visualization indicate that VR enhances spatial awareness, problem-solving efficiency, and design iteration by providing embodied experiences that allow users to perceive proportions, materiality, and spatial relationships more intuitively (Borg

et al., 2021; Portman, Natapov, & Fisher-Gewirtzman, 2015). While screen-based models remain useful for rendering and preliminary visualization, research suggests that fully immersive VR leads to deeper cognitive engagement and a more refined spatial understanding, which are crucial in architectural education (Pober & Wölfel, 2020). By leveraging VR for design analysis, students can better understand how their projects interact with real-world contexts, such as light, scale, and materiality, which were often difficult to evaluate through 2D plans or static 3D models.

The seamless integration between CAAD and VR tools represents a growing area of research, with many academics now focusing on how this combination can enhance the workflow in architectural education. Despite these advancements, there are still gaps in current research related to the long-term impacts of using VR on students' design thinking and decision-making processes, as well as how well they adapt to this new workflow compared to traditional methods. More studies are required to investigate the impact of VR on improving design accuracy, feasibility, and overall learning outcomes in architectural studios.

3.6.3 AR Interactive Design and Real-time Feedback

Augmented Reality (AR) enables students to overlay digital elements onto physical models, offering real-time feedback and interactive design possibilities. This capability allows students to visualize modifications instantly, facilitating iterative design processes and enhancing design decision-making. For example, AR can be used to instantly project how different materials or lighting conditions affect designs, allowing students to make more informed choices and better understand the implications of their decisions (Sánchez-Sepúlveda et al., 2019). In their study, Sánchez-Sepúlveda et al. conducted a series of AR-based experiments to evaluate how students engaged with AR during the design process. The results indicated that students demonstrated an

enhanced understanding of materiality and lighting, and their ability to iterate on designs improved due to the instant feedback provided by the AR platform.

Additionally, AR applications have proven particularly useful in architectural fieldwork and site analysis. By overlaying digital information on physical environments, AR can provide critical contextual data such as topography, historical information, and design guidelines directly in the user's field of view (Diao & Shih, 2019). This allows students to analyze site-specific factors more effectively and produce designs that are contextually responsive. Diao and Shih (2019) tested AR tools for on-site analysis with architectural students, observing that participants were able to engage more deeply with site-specific design challenges, improving their spatial awareness and decision-making abilities in situ.

While AR provides numerous benefits, such as real-time design updates and enhanced site analysis, there are still challenges to overcome, including the costs of AR hardware and the learning curve associated with using such tools in educational settings. Nonetheless, the potential for AR to transform architectural pedagogy, particularly in integrating real-time contextual information with design processes, is immense.

3.6.4 AR Availability Engagement and Motivation

Research has demonstrated that AR increases student engagement and motivation by making learning more interactive and enjoyable. The ability to interact with augmented models and receive immediate visual feedback encourages students to experiment and explore different design ideas. This hands-on approach aligns with the experiential nature of architectural education, fostering a deeper understanding and retention of architectural concepts (Linh, 2020; Saadon et al., 2020). For example, Martín-Gutiérrez et al. (2015) studied how AR-based exercises in architectural courses improved students'

spatial perception and design skills, showing how this technology can create a more immersive learning experience.

Augmented Reality (AR) applications in architectural education can simulate architectural scenarios, providing students with an engaging, visual experience that enhances their understanding and retention of complex concepts (Hajirasouli & Banihashemi, 2022; Diao & Shih, 2019). For instance, in fieldwork or design studios, AR can be used to overlay digital information on real-world settings, allowing students to visualize architectural projects in the actual physical environment, which is crucial for understanding context-sensitive designs. One example includes using AR to visualize the impact of materials and structural elements within a given architectural context.

Recent advancements in AR technologies, such as Gravity Sketch and Arkio, have significantly improved the accessibility of AR by enabling its use on everyday devices like smartphones and tablets. These developments lower the barrier for entry, reducing user interface challenges and making it more feasible for wide-scale studio applications (Linh, 2020). The ability to use AR without specialized hardware increases student participation and engagement, allowing for real-time collaboration and feedback during studio work.

3.7 Common Research Strategies for Immersive Technologies in Architectural Education

Designing research on VR and AR requires understanding the variety of methods and strategies employed by other researchers in the field. This section discusses the latest research trends, methodologies, and strategies scholars use to investigate the impact of VR and AR on education, particularly in architectural education.

Recent studies have utilized a combination of qualitative, quantitative, and mixed-method approaches to explore the multifaceted impacts of VR and AR. These methodologies provide a comprehensive understanding of how immersive technologies influence learning outcomes, engagement, and cognitive development. For instance, Huang et al. (2018) combined qualitative interviews with quantitative performance metrics to examine the effects of VR on spatial cognition and design skills. Similarly, Gül and Gu (2019) employed a mixed-method approach to assess the collaborative learning potential of MR environments in architectural studios. These research strategies enable educators to assess the effectiveness of VR and AR technologies in a nuanced manner, ensuring that both the learning process and outcomes are critically evaluated. The combination of these research methodologies helps create a richer picture of how immersive technologies impact education. Qualitative methods such as interviews and focus groups provide insights into students' experiences and perceptions, while quantitative data from tests, assignments, and user analytics offer objective measures of performance and engagement. Mixed-method studies allow for the triangulation of data, enhancing the reliability of the results and offering a more holistic view of VR and AR's role in architectural education.

3.7.1 Qualitative Research Methods

Qualitative research methods have been widely adopted to capture students and educators' experiences and perceptions when using VR and AR technologies in architectural education. Researchers often use interviews, focus groups, and ethnographic studies to gather rich, in-depth insights into how these immersive tools influence the learning process.

For instance, Cheng and Wang (2019) conducted semi-structured interviews with architecture students, revealing that VR improved students' spatial awareness and design creativity. This study emphasized how VR provided an immersive environment, encouraging deeper engagement with design projects. This kind of qualitative approach

is particularly relevant to my own research as it offers a way to explore students' reflective processes when engaging with VR in a design studio setting.

Similarly, Birt et al. (2018) used focus groups to investigate the impact of AR on collaborative learning, emphasizing how AR enhanced real-time collaboration and feedback within student teams. This aligns with my research objectives, as it points to the potential for AR to foster interaction and teamwork in architectural education. However, my research will focus on exploring new dimensions of immersive learning, particularly how AR and VR influence not just collaboration but also independent problem-solving and design iteration.

In this study, qualitative methods such as interviews and focus groups will be critical in capturing the experiential nature of VR and AR learning environments and how they influence not only collaborative work but also individual creativity and decision-making in the design process. Thus, while similar qualitative approaches have been used in previous studies, my research aims to contribute new insights by focusing on the interplay between immersive technologies and independent, as well as collaborative, design thinking.

3.7.2 Quantitative Research Methods

Quantitative research methods are employed to measure the effectiveness of VR and AR technologies on educational outcomes through structured data collection and statistical analysis. Surveys, experiments, and quasi-experimental designs are commonly used to gather empirical data.

For example, Radi et al. (2021) conducted a quasi-experimental study to assess the impact of VR on architectural students' spatial skills. The researchers used pre-and post-

tests to measure changes in spatial ability, comparing the performance of students who used VR tools with those who used traditional methods. The study found that students engaged with VR significantly improved spatial reasoning and design skills. Using statistical analysis enabled the researchers to quantify the educational benefits of VR, providing robust evidence of its effectiveness.

Another quantitative approach is seen in the work of Liu et al. (2020), who utilized Likert-scale surveys to evaluate student satisfaction and engagement with AR applications in a design course. By analyzing survey responses from a large sample of students, the researchers identified key factors influencing user satisfaction, such as the ease of use and perceived usefulness of AR tools. This quantitative method provided valuable insights into the overall impact of AR on student learning experiences.

3.7.3 Mixed-Method Approaches

Mixed-method approaches combine qualitative and quantitative research methods to provide a holistic understanding of the impact of VR and AR technologies. These approaches leverage the strengths of both methodologies, offering a comprehensive analysis of educational outcomes.

Angulo et al. (2015) employed a mixed-method approach in their study on integrating VR in architectural education. The researchers used surveys to collect quantitative data on student performance and engagement while conducting in-depth interviews to gather qualitative insights into students' experiences. The study found that students who used VR were more engaged in their design process, exhibited improved spatial awareness, and displayed higher levels of creativity compared to those using traditional methods. This approach allowed the researchers to triangulate their findings, ensuring a more nuanced understanding of how VR influences learning outcomes.

In another example, Diao and Shih (2019) used a combination of case studies, surveys, and observational methods to explore the use of AR in fieldwork and site analysis. Their findings revealed that AR tools facilitated real-time feedback during fieldwork, which significantly improved students' analytical and critical thinking skills. The AR applications allowed students to overlay digital data onto real-world environments, helping them visualize complex spatial and structural elements more effectively. The mixed-method approach enabled a thorough investigation of AR's educational impact, capturing measurable outcomes as well as personal experiences, providing a well-rounded evaluation of the technology's effectiveness in enhancing learning.

3.7.4 Experimental and Quasi-Experimental Designs

Experimental and quasi-experimental designs are widely used to investigate causal relationships between VR/AR technologies and educational outcomes. These designs allow researchers to control various factors and isolate the effects of the intervention, providing more reliable evidence for their findings.

Chen et al. (2019) conducted a randomized controlled trial to examine the effects of VR-based learning on architectural students' design performance. Participants were randomly assigned to either a VR or traditional learning group. The VR group used immersive VR environments for their design projects, while the control group used conventional tools. The study found that the VR group demonstrated higher levels of creativity and spatial understanding, suggesting that VR can significantly enhance design education. Using a controlled experimental design provided strong evidence for the causal effects of VR, and these results contribute to the growing body of evidence supporting VR as a valuable tool in architectural pedagogy. However, the study also highlighted the need for further research to explore how the long-term use of VR affects

knowledge retention and design capabilities, identifying a gap for future studies to build upon.

In a quasi-experimental study, Wang and Dunston (2018) compared the learning outcomes of students using AR for construction management training with those using traditional methods. The researchers employed a non-equivalent group design, where participants were selected based on their prior experience with AR. Pre- and post-tests were administered to measure knowledge gains, and the results indicated that AR significantly improved students' understanding of construction processes. The quasi-experimental design allowed for a practical investigation of AR's educational impact while accounting for real-world constraints, such as varying levels of prior AR exposure. The findings reinforce the potential of AR to improve learning outcomes in construction education, though further research is needed to explore AR's scalability and application in different architectural domains.

3.7.5 Case Studies

Case studies are a valuable research method for exploring the implementation and impact of VR and AR technologies in specific educational contexts. This method allows for an in-depth examination of individual cases, providing detailed insights into the practical application and real-world challenges of these technologies.

Dorta et al. (2016) conducted a case study on using VR in a collaborative design studio. The researchers documented the experiences of students and instructors as they used VR tools for collaborative design projects. The case study revealed that VR facilitated better communication and idea-sharing among students, leading to more innovative and creative design solutions. The detailed documentation of the case provided valuable insights into the practical benefits and challenges of using VR in architectural design education, highlighting the positive effects of immersive technologies on collaborative

learning and design outcomes. However, the study also noted the technical challenges, such as the learning curve associated with VR tools, which impacted the efficiency of the design process, identifying areas for improvement.

In another case study, Bimber and Raskar (2005) explored the use of AR in a historical preservation course. The researchers implemented AR tools to overlay historical images and information onto physical landmarks, providing students with an immersive and interactive learning experience. This approach helped students better understand historical contexts and preservation techniques by blending physical and digital environments. The rich, contextual data gathered through the case study method demonstrated how AR could enhance architectural education by offering real-time contextual information that supports a deeper understanding of the subject matter.

Both case studies illustrate how VR and AR can be applied in educational settings, offering substantial benefits for engagement and understanding. However, they also highlight the importance of addressing the technical and logistical challenges associated with integrating these technologies into curricula.

3.7.6 Longitudinal Studies

Longitudinal studies track the impact of VR and AR technologies on educational outcomes over an extended period. These studies provide valuable insights into the long-term effects of immersive technologies on learning, cognitive development, and professional proficiency.

Radi et al. (2021) conducted a longitudinal study to examine the sustained impact of VR on architectural students' design skills. The researchers followed a cohort of students over three years, periodically assessing their performance and engagement with VR tools. The study found that the continued use of VR led to significant improvements in spatial reasoning, creativity, and design proficiency. These improvements were

especially notable in the students' ability to visualize complex spatial relationships and apply their learning in innovative design solutions. The longitudinal approach provided robust evidence of the lasting benefits of VR in architectural education, demonstrating how immersive technologies can deepen understanding and skill development over time.

In another longitudinal study, Mikropoulos and Natsis (2011) investigated the long-term effects of AR on science education. The researchers tracked students' performance and attitudes toward science over two academic years, comparing those who used AR tools with those who did not. The study revealed that students who consistently used AR demonstrated higher engagement, improved problem-solving abilities, and greater academic achievement in science subjects. By analyzing student progress over an extended period, the study offered a comprehensive evaluation of AR's sustained impact on educational outcomes, highlighting its potential for enhancing both interest and competence in complex subjects.

These longitudinal studies underscore the value of immersive technologies like VR and AR in promoting long-term cognitive development and academic achievement. They also emphasize the importance of consistent integration of these tools within the curriculum to maximize their educational benefits. While these studies demonstrate positive learning outcomes, some researchers have noted that the level of student engagement plays a crucial role in determining the effectiveness of immersive learning. For instance, students who actively engage with VR and AR environments—by iterating on designs, participating in collaborative tasks, and reflecting on spatial experiences—tend to show greater cognitive development than passive users (Makransky & Petersen, 2021; Radianti et al., 2020). Although some studies accounted for engagement variations, others primarily focused on the overall educational impact of VR/AR without differentiating between high and low-engagement learners. This highlights the need for further research

on how different levels of interaction influence the effectiveness of immersive technologies in architectural education.

3.7.7 Meta-Analyses and Systematic Reviews

Meta-analyses and systematic reviews synthesize findings from multiple studies to provide an overarching understanding of the impact of VR and AR technologies on education. These methods aggregate data to identify trends, assess effectiveness, and guide future research, making them valuable tools in educational research, including in areas beyond architecture.

Freina and Ott (2015) conducted a systematic review of VR applications across various educational disciplines, including engineering, medicine, and the social sciences. The review highlighted VR's significant positive effects on student engagement, spatial understanding, and learning outcomes, emphasizing its utility as a tool for enhancing the educational experience. By synthesizing data from numerous studies, Freina and Ott provided a broad and comprehensive overview of VR's benefits in education while also identifying gaps and areas requiring further research.

In a meta-analysis, Riva et al. (2016) examined the psychological and behavioral effects of VR in educational settings. The researchers aggregated data from a wide range of experimental studies to assess the impact of VR on cognitive function, emotional well-being, and social behavior. Their meta-analysis revealed that VR positively influenced cognitive and emotional outcomes, supporting its use as an effective educational tool. This study's rigorous statistical analysis further validated VR's potential for fostering engagement and enhancing learning experiences across various disciplines.

Although these meta-analyses do not focus explicitly on architecture, they offer valuable insights into the broader implications of VR and AR technologies in education. The findings can inform architectural education by highlighting the general benefits of

immersive technologies, which may be applied to design education to improve spatial reasoning, creativity, and collaborative learning.

3.7.8 Comparative Studies

Comparative studies are essential for understanding the differences between immersive technologies like VR and AR and traditional teaching methods. They offer valuable insights into the relative effectiveness and educational value of these technologies in architectural education.

Liu et al. (2020) conducted a comparative study that evaluated the performance, engagement, and satisfaction levels of architecture students using VR, AR, and traditional learning methods. The study revealed that both VR and AR significantly enhanced students' spatial understanding and creativity compared to conventional teaching approaches. However, the technologies excelled in different areas: VR was found to be superior for immersive visualization and providing a more comprehensive sense of scale and space, while AR was more effective for interactive learning and offering real-time feedback. This comparative approach provided a nuanced understanding of the distinct advantages and limitations of VR and AR in architectural education.

In another study, Radi et al. (2021) compared the effects of VR and traditional sketching on students' creativity, spatial reasoning, and design quality. The research found that VR offered a more immersive and interactive environment, fostering greater creativity and spatial understanding. On the other hand, traditional sketching was valued for its simplicity, ease of use, and the tactile experience it provided. The study concluded that both VR and traditional sketching have their strengths, suggesting that the two approaches could complement each other in a comprehensive architectural curriculum.

Comparative studies like these highlight the value of integrating both immersive technologies and traditional methods to maximize educational outcomes. By understanding the strengths and weaknesses of each approach, educators can make more informed decisions about how best to incorporate VR and AR into architectural education.

3.8 Immersive Technologies: Design Tool vs Collaborative Design Media

3.8.1 VR as a Design Tool

In its early stages, VR was primarily regarded as a supplementary tool in architectural design, mainly used for post-modelling visualization and spatial analysis. Angulo et al. (2015) explored how VR could be employed to enhance post-modelling visualization by allowing students to export CAD models into immersive VR environments. This capability enabled students to walk through their designs virtually, offering a more intuitive grasp of spatial relationships, scale, and proportions that is difficult to achieve through traditional 2D drawings or screen-based 3D models. Research has shown that immersive visualization enhances comprehension of spatial dynamics, making it a valuable addition to architectural education (Radi et al., 2021).

However, early VR technology faced several limitations that restricted its utility. One of the main challenges highlighted by Dorta et al. (2016) was the cumbersome nature of the model exportation process. Transferring detailed CAD models into VR environments was time-consuming and often resulted in the loss of design details, thus limiting the technology's effectiveness. Additionally, Liu et al. (2020) identified the lack of fluid interaction as a significant drawback, noting that early VR systems did not allow for seamless modification of designs during virtual walkthroughs. This constraint meant that VR could not easily support iterative design processes, limiting its use primarily to visualization rather than as an active design tool.

The lack of interactivity in early VR systems also posed challenges in integrating VR into the full design workflow. Students and professionals alike struggled with the inability to make real-time changes to their designs within the virtual environment. As Radi et al. (2021) observed, the rigidity of early VR tools resulted in a separation between design creation and spatial evaluation, restricting the technology's potential for enhancing the entire design process.

While VR provided valuable spatial insights, these limitations prevented it from becoming an integral part of the design workflow (Birt et al., 2018). However, with technological advancements in hardware and software, VR is evolving beyond just a tool for visualization. Contemporary VR platforms now support real-time manipulation of models, enabling iterative design processes within virtual environments (Bartosh & Anzalone, 2019). The shift toward more interactive and collaborative VR tools has broadened its applications in design education, allowing students and professionals to engage more deeply with their designs at all stages of development. This evolution suggests that VR is gradually becoming a core component of architectural education and practice, enhancing both the design and presentation stages (Liu et al., 2020).

3.8.2 Evolution of VR Integration

The integration of VR into architectural design education has significantly evolved with advancements in both hardware and software. Modern VR platforms such as Gravity Sketch and Arkio provide interactive design capabilities, enabling students and designers to modify their work in real-time and engage in collaborative design sessions. This shift has expanded VR's role beyond mere visualization, allowing it to be used in conceptual design and iterative development processes (Radi et al., 2021). The ability to visualize and modify designs interactively has made VR a valuable tool for early-stage design, where ideas are still fluid and open to exploration.

Huang et al. (2018) conducted a study on the use of VR in facilitating early-stage design processes. The researchers developed a VR simulation to explore how users interact with designed spaces, focusing on spatial usage and design efficiency. By immersing participants in virtual environments, the study provided insights into how people move through and experience space, enabling designers to refine their concepts based on user feedback. The study concluded that VR offers a unique advantage in understanding human interactions with space, which is often difficult to achieve with traditional design methods.

Zhang et al. (2018) took a different approach by incorporating biometric feedback to evaluate emotional and physiological responses to architectural designs. In their study, participants were immersed in virtual environments, and their biometric data—such as heart rate and galvanic skin response—were recorded to assess their emotional engagement with the designs. The researchers found that the integration of biometric feedback in VR allowed for a deeper understanding of how users emotionally and physically respond to spaces. This method provided a novel approach to evaluating user experience, offering architects the ability to gauge the emotional impact of their designs during the development stage.

These studies highlight how VR has evolved from a visualization tool to an interactive design platform capable of influencing early-stage design decisions. The integration of real-time feedback and user interaction data has expanded VR's utility, allowing it to address both practical design challenges and the subjective experience of users. As VR technology continues to improve, its role in design education is likely to grow, offering students and professionals a more immersive and responsive environment for exploring and refining architectural concepts (Birt et al., 2018).

3.8.3 Conceptual Design Tools

The implementation of VR in design education has evolved from its initial role as a supplementary tool for visualization to becoming an integral part of the design process. Early studies treated VR primarily as a conceptual design tool, exploring its potential at different stages of the design workflow. Angulo et al. (2015) and Dorta et al. (2016) both investigated VR's use during the later stages of design, focusing on the exportation of CAD models into VR environments. These studies underscored the technological advancements that allowed students to explore their designs in immersive virtual spaces. Despite some limitations, such as the cumbersome process of importing models at the time, VR provided valuable spatial insights that were otherwise challenging to achieve with traditional methods.

Research by Abdelhameed (2011) showed that VR was most effective in augmenting students' creativity during the final stages of design. The study attributed this to the constraints of early VR technology, which made real-time design iteration difficult. Nevertheless, VR allowed students to experience their designs through virtual walkthroughs, offering a level of spatial understanding that traditional 2D methods could not replicate. Similarly, Campbell and Wells (2001) highlighted how VR enabled students to gain a deeper connection with their designs by allowing them to inhabit and explore the architectural spaces they created.

As VR hardware and software have advanced, its application in design education has expanded. Modern VR platforms offer interactive features that facilitate not only visualization but also early-stage conceptual design and iterative development. Huang et al. (2018) utilized agent-based modeling within VR environments to simulate user interactions with designed spaces. This approach provided valuable feedback on spatial usage, design efficiency, and user experience, helping students understand the real-

world implications of their design decisions. Similarly, Zhang et al. (2018) introduced biometric feedback in VR settings to evaluate emotional and physiological responses to architectural designs. By measuring heart rates, skin conductance, and other biometric indicators, the study offered a novel way to assess how users emotionally and physically responded to various architectural environments.

These studies demonstrate the evolution of VR from a tool primarily used for visualizing finalized designs to an interactive platform that actively supports conceptual development and iterative design refinement. Unlike traditional static visualization methods, VR enables students to engage with their designs dynamically, test spatial relationships in real-time, and receive immediate feedback from both users and tutors.

As VR technology continues to advance, it will likely play an increasingly critical role in shaping design education, allowing students to iteratively refine their work based on feedback gathered from immersive user evaluations. By integrating user experience data and real-time design modifications, VR enhances not only the design process itself but also students' ability to critically assess and improve their creative solutions, aligning with the core objectives of this research (Birt et al., 2018).

3.8.4 Interactive and Collaborative Tools

Recent research has increasingly emphasized the interactive and collaborative potential of VR and AR in architectural education. Bartosh and Anzalone (2019) highlighted the use of VR in integrating technical capabilities into design education. Their course, Special Topics in Construction, utilized VR to allow students to sequence construction processes and understand building assemblies in an immersive and interactive manner. This approach marked a significant shift from using VR purely as a visualization tool to a more comprehensive educational platform that enhances technical skills.

In their study, Bartosh and Anzalone (2019) required students to model building components with precise dimensions and connections, closely simulating real-world construction processes. The integration of VR headsets provided students with the opportunity to visualize and sequence the assembly of these components in real-time, offering a deeper understanding of construction logistics, material behavior, and the spatial relationships within a building system. The detailed nature of this process allowed students to explore construction challenges in a virtual environment before dealing with them in a physical setting, bridging the gap between theoretical knowledge and practical application.

This interactive approach to using VR reflects the broader trend of leveraging immersive technologies for hands-on learning experiences in architectural education. The ability to interact with models and components in a virtual environment allows students to experiment with design choices, observe immediate feedback, and collaborate with peers. These capabilities make VR and AR valuable tools for fostering collaborative learning, where students and instructors can engage in discussions, provide feedback, and refine designs collectively (Redondo et al., 2013). Moreover, collaborative VR platforms enable multiple users to inhabit the same virtual space, facilitating teamwork on complex design projects and simulating professional architectural practices.

As VR and AR technologies continue to evolve, their role in promoting interactive and collaborative learning environments is expected to grow. These tools offer unique opportunities for architectural students to gain practical experience, improve problem-solving skills, and develop a more profound understanding of construction processes and design methodologies.

3.9 Conclusion

Research on the integration of VR and AR in education demonstrates significant potential for enhancing learning through immersive and interactive experiences. A wide range of methodologies, from Quasi-Experimental designs to mixed-method approaches, have been used to explore the impacts of these technologies. Despite challenges related to accessibility and practical implementation, the evidence shows that VR and AR can profoundly transform educational practices, particularly in fields like architecture, where visualization and interaction are essential components of the learning process.

In architectural education, the evolution of VR and AR has been substantial, transitioning from supplementary visualization tools to comprehensive platforms for design and analysis. The interactive and collaborative capabilities of modern VR and AR technologies have introduced new opportunities for enriching the educational experience, making learning more engaging and effective. Through immersive environments, students can gain deeper insights into spatial relationships, test design hypotheses, and collaboratively develop innovative solutions. These tools better prepare students for the complex demands of the architectural profession, where spatial understanding and design experimentation are critical.

Addressing current challenges—such as ensuring accessibility, reducing technical complexity, and seamlessly integrating these technologies into educational programs—remains a top priority for researchers and educators. To ensure that all students can benefit from these innovations, it is essential to pursue equitable access to VR and AR tools through strategic funding, institutional support, and scalable implementation strategies. Future research should focus on conducting long-term studies to explore the sustained impact of immersive technologies on learning outcomes, creativity, and engagement. In addition, attention should be given to developing VR and AR technologies that cater specifically to the needs of architectural education, such as incorporating real-time design feedback and collaborative features.

Overall, VR and AR have already begun to significantly influence architectural education by offering immersive, interactive, and collaborative learning experiences. These technologies enhance students' spatial cognition, design skills, and overall engagement with architectural concepts. As VR and AR continue to develop and become more integrated into architectural curricula, they will provide even more innovative and effective educational tools. The evolution of these technologies will help educators create dynamic learning environments that prepare students for the professional practice of architecture in a constantly evolving field.

Looking Forward

This chapter has provided a comprehensive overview of the current state of VR and AR in architectural education, identifying key trends, methodologies, and challenges. It has highlighted how these immersive technologies are being used and the benefits they offer in transforming educational practices. The gaps identified, such as the need for more sustained research and equitable access to VR and AR technologies, present opportunities for further exploration in the field. The following chapter will build on this foundation by introducing the research methodology employed in this study and exploring how these gaps in the literature will be addressed through empirical investigation.

Chapter 4: Research Methodological Study

4.0 Introduction

This chapter outlines the research methodology employed to investigate the role of Virtual Reality (VR) and Augmented Reality (AR) in enhancing architectural education. The methodology is designed to address the gaps identified in Chapters 2 and 3, particularly the need for empirical studies that explore the integration of immersive technologies into the design learning process. Building on the historical evolution of architectural pedagogy discussed in Chapter 2, this chapter outlines the methodology used to investigate the integration of immersive technologies, such as Virtual Reality (VR) and Augmented Reality (AR), into architectural education. As architectural design continues to evolve, the need for new pedagogical strategies that incorporate these advanced tools is increasingly apparent. This chapter discusses the research design, data collection methods, and analysis strategies employed to assess the impact of VR and AR on learning outcomes, student engagement, and design proficiency. By situating this study within the broader historical context of design technologies, this research aims to provide insights that contribute to the ongoing evolution of architectural education. Chapter 3 highlighted the growing interest in VR and AR within architectural pedagogy, yet also revealed a scarcity of rigorous research that systematically examines their impact on student engagement, spatial understanding, and collaborative learning. Chapter 3 built upon this by demonstrating the potential of VR and AR to transform both individual and group learning experiences, though the practical implementation of these technologies remains underexplored.

To address these gaps, a mixed-methods approach has been selected, combining both qualitative and quantitative data collection techniques. This approach allows for a comprehensive understanding of how VR and AR can be integrated into architectural education to improve learning outcomes. Qualitative methods such as interviews and focus groups will capture the nuanced experiences of both students and educators, while quantitative methods

like surveys and performance assessments will provide measurable data on the effectiveness of these technologies. Triangulating these data sources, this study aims to provide a holistic view of the impact of VR and AR on architectural education.

The following sections detail the specific research strategies, tools, and procedures that will be employed, along with an explanation of how these methods align with the overall research questions. This chapter discusses the methodology, outlining the research strategies and techniques needed for data collection, presentation, and analysis. Section 4.2 addresses the research philosophies that underpin the study's beliefs and approaches. Section 4.3 explores the research methodology and methods, while section 4.4 justifies the use of mixed methods to answer the research questions posed in chapter one. Section 4.5 provides an overview of data sources and collection methods. The research sample and population are discussed in section 4.6, with data analysis procedures detailed in section 4.7. Section 4.8 describes the specific research methods employed. Finally, section 4.9 addresses methodological limitations and ethical considerations. The chapter concludes with a summary in section 4.10.

4.1 Research Philosophies/Paradigm

Research philosophy involves the development of knowledge and the nature of that knowledge (Creswell, 2014). It is categorized into four main types: ontology, epistemology, methodology, and methods (Scotland, 2012). Ontology is concerned with the nature and structure of reality, addressing questions about what exists in the world. Epistemology, on the other hand, deals with the nature and scope of knowledge, including its sources, limitations, and validity (Carter & Little, 2007). Methodology refers to the overarching strategy and rationale of the research project, encompassing the framework that guides data collection and analysis. Methods are the specific techniques and procedures used to gather and analyze data (Carter & Little, 2007; Scotland, 2012).

These philosophical foundations influence the researcher's worldview and methodological choices. For instance, a positivist approach is rooted in the belief that reality is objective and can be measured and quantified, typically leading to the use of quantitative methods. In contrast, social constructivism posits that reality is socially constructed and understood through subjective experiences, aligning more closely with qualitative methods. Post-positivism and pragmatism offer middle-ground perspectives, blending elements of both positivism and constructivism (Creswell & Plano Clark, 2017).

- **Positivism Paradigm:** A scientific approach that is objective and often associated with quantitative methods, where the researcher remains unbiased until hypotheses are tested.
- **Social Constructivism:** A subjective approach associated with qualitative methods, focusing on social contexts.
- **Post-Positivism:** Balances positivism and social constructivism, allowing for some subjectivity while being rooted in positivist ideals.
- **Pragmatism:** A flexible approach guided by research questions, not strictly adhering to any single paradigm.

Positivist researchers seek to quantify precise knowledge using scientific methods to present empirical findings (Henning et al., 2004). This approach evaluates subjects through theories and models based on objective facts and observations using quantitative methods (Henning et al., 2004; Veal, 2006; Ayikoru, 2009).

The debate continues over which research philosophies best suit different subjects in natural or social sciences (Bryman, 1984; Steinzetz, 2004). Polit and Beck (2008) argue that quantitative research aligns with natural sciences, whereas Babbie (2007) suggests that qualitative positivism pertains to social sciences. Johnson and Onwuegbuzie (2004) emphasize that these

debates might be theoretical, noting that methods and data collection are not strictly tied to epistemological beliefs, although these beliefs guide research tasks and method choices (Creswell, 2009; Nightingale, 2011).

This research aligns with Tashakkori and Teddlie (1998), who assert:

"A pragmatic stance allows the use of various research methods, often associated with mixed-methods studies combining both qualitative and quantitative methods" (Tashakkori and Teddlie, 1998, as cited in Reeves, 2009, pp. 75-76).

This research adopts a pragmatic approach. Pragmatism is characterized by its flexibility and focus on 'what works' to address the research questions. It allows the integration of various methods, typically associated with mixed-methods research, to provide comprehensive and multifaceted insights (Tashakkori & Teddlie, 2010).

4.2 Research Methods and Methodology: An Overview

Research methods encompass the procedures, tools, and techniques used in conducting and analyzing research (Schwandt, 2001). Selecting appropriate research methods is crucial for lending credibility to the project and validating the chosen methods (Fellows and Liu, 2003). Research methodology refers to the principles and logical procedures applied to investigate and solve research problems, along with the rationale behind the selected methods (Fellows and Liu, 1997; Kothari, 2007; Sridhar, 2009). The use of appropriate research methods and methodology is essential for this study to achieve its aims and objectives.

4.2.1 Research Approach

Research methods are traditionally categorized into qualitative and quantitative approaches (Onwuegbuzie and Leech, 2005). These methods encompass data collection, analysis, and interpretation, with each step being critical and commonly

employed by researchers (Denzin and Lincoln, 2005; Onwuegbuzie and Leech, 2005; Domegan and Fleming, 2007; Myers, 2009).

Qualitative methods explore and interpret individual perspectives, particularly in areas with limited prior knowledge. This approach involves techniques such as interviews, opinion polls, direct observations, and documentary analysis, translating data into words (Denzin and Lincoln, 2005; Domegan and Fleming, 2007). These methods are inductive, do not require a hypothesis, and position the researcher as the primary instrument of data collection and analysis (Denzin and Lincoln, 2005; Saunders, 2009). Additionally, qualitative research provides detailed insights into the behaviors of the subjects studied (Brannen, 1992).

In contrast, quantitative research is empirical and deductive (Hinchey, 2008; Saunders, 2009). It relies on tools such as questionnaires, surveys, and experiments to gather numerical data for statistical analysis (Myers, 2009). Quantitative methods interpret opinions, compare variables, and analyze data to identify trends, causality, and specific population metrics. This approach typically examines attitudes rather than behaviors and includes experimental, survey, and quasi-experimental designs (Brannen, 1992; Naoum, 1998; Social Justice Institute, 1999).

Qualitative methods provide in-depth insights through written interpretations, whereas quantitative methods offer broader understanding through numerical data (Denzin and Lincoln, 2005; Domegan and Fleming, 2007; Myers, 2009). The selection of methods should therefore be guided by the goal of achieving reflective findings that effectively address the research questions (Patel, 2006).

This study adopts a third approach, combining qualitative and quantitative methods—known as mixed-methods research. According to Johnson et al. (2007) and Hart et al. (2009), this approach integrates both methodologies to achieve more accurate and

comprehensive information through triangulation (Maxwell, 2005; Canales, 2012). Mixed-methods research captures both detailed and general reflections of an inquiry, including participants' opinions (Creswell and Clark, 2007). Furthermore, mixed-methods allow for an analytical framework that encompasses literature review insights and investigative findings from both individuals and groups (Brannen, 1992; McDougall and Beattie, 1998). These arguments suggest that mixed-methods research offers a broad inquiry scope, from small-scale to large-scale studies involving human subjects.

4.2.2 Processes in Mixed Methods Research

Mixed-methods research involves a systematic integration of quantitative and qualitative data collection and analysis processes. This integration can occur at various stages of the research process, including data collection, analysis, and interpretation (Creswell & Plano Clark, 2017). The processes involved in mixed methods research typically include the following steps:

1. **Research Design:**

- **Sequential Designs:** In sequential designs, one phase of data collection and analysis is followed by another. For example, quantitative data might be collected and analyzed first, followed by qualitative data to explore the initial results in more depth (Ivankova et al., 2006). Alternatively, qualitative data might be gathered first to develop a theoretical framework, followed by quantitative data collection to test the emerging theory (Teddlie & Tashakkori, 2009).
- **Concurrent Designs:** Concurrent designs involve collecting both qualitative and quantitative data simultaneously. This approach allows for the triangulation of data, providing a comprehensive perspective on

the research problem. The data are collected independently but analyzed together to draw integrated conclusions (Morse & Niehaus, 2016).

2. **Data Collection:**

- **Quantitative Methods:** Surveys, questionnaires, and structured observations are commonly used to collect numerical data. These methods are designed to measure variables and test hypotheses using statistical techniques (Creswell & Plano Clark, 2017).
- **Qualitative Methods:** Interviews, focus groups, and unstructured observations are employed to gather rich, descriptive data. These methods aim to understand participants' experiences and perspectives in depth (Denzin & Lincoln, 2018).

3. **Data Analysis:**

- **Quantitative Analysis:** . To analyze numerical data, this study employed descriptive statistics (e.g., means, standard deviations, and frequencies) to summarize trends, inferential statistics (e.g., t-tests, ANOVA) to compare groups and test significance, and multivariate analysis (e.g., regression analysis) to explore relationships between variables. Statistical analyses were conducted using SPSS due to its user-friendly interface and robust statistical testing capabilities, particularly for handling ANOVA, regression modeling, and factor analysis (Field, 2018). R was also used for its advanced data visualization and customizable statistical modeling functions, ensuring flexibility in analyzing complex relationships within the dataset. The combination of descriptive, inferential, and multivariate techniques was chosen to provide both a

broad overview of patterns and deeper insights into statistical relationships, ensuring a comprehensive understanding of the impact of immersive technologies on creativity, communication, and confidence in architectural education.

- **Qualitative Analysis:** Techniques such as thematic analysis, grounded theory, and content analysis are used to identify patterns and themes within qualitative data. NVivo or ATLAS.ti are popular software tools for managing and analyzing qualitative data (Braun & Clarke, 2019).

4. Integration of Data:

- **Data Merging:** Data from qualitative and quantitative sources are merged to provide a comprehensive understanding of the research problem. This can be achieved by combining datasets, cross-referencing findings, and integrating results during interpretation (Fetters et al., 2013).
- **Data Connecting:** In sequential designs, findings from one phase inform the data collection in the subsequent phase. For instance, qualitative findings might be used to develop a survey instrument, or quantitative results might identify key themes for further exploration through interviews (Creswell & Plano Clark, 2017).

5. Interpretation:

- **Interpretative Synthesis:** The final step involved synthesizing the quantitative and qualitative findings to draw comprehensive conclusions about the impact of immersive technologies on architectural education.

This synthesis accounted for:

- **Strengths of the Methods:** The quantitative analysis provided statistically validated insights into trends related to creativity, communication, and confidence, while the qualitative data added rich contextual depth, capturing personal experiences and nuanced perceptions.
- **Limitations of the Methods:** The study acknowledged that self-reported measures (e.g., surveys on confidence and creativity) may have introduced response bias, and sample size constraints in qualitative interviews could limit generalizability.
- **Context of the Data:** Findings were analyzed within the framework of studio-based architectural education, considering the unique pedagogical challenges and the role of immersive technologies in enhancing design-based learning.
- **Actionable Insights & Recommendations:** The synthesis suggested that VR was most effective for conceptual creativity, AR enhanced real-time collaborative communication, and MR supported iterative design refinement. Based on these findings, recommendations included progressive integration of immersive tools into architectural curricula, targeted faculty training programs, and further studies on long-term cognitive effects.

By integrating multiple perspectives, the interpretation process ensured that the conclusions were grounded in empirical data, critically assessed for validity, and practically relevant for educational innovation (Teddle & Tashakkori, 2009). By following these structured processes, mixed-methods research provides a robust framework for exploring complex research questions. The integration of qualitative and quantitative data enriches the analysis, allowing for a more nuanced understanding of the research problem and enhancing the validity and reliability of the findings (Johnson et al., 2007).

4.3 Rationale for Adopting Mixed Methods Research

This study adopts the mixed-method research approach primarily because it integrates and reconciles diverse perspectives, meanings, and relationships (Morse, 2016). Johnson et al. (2007) explain that mixed-methods research merges theory with practice, stating:

"Today, the primary philosophy of mixed research is pragmatism. Mixed methods research considers multiple viewpoints, perspectives, positions, and standpoints (always including those of qualitative and quantitative research)" (Johnson and Onwuegbuzie et al., 2007, p. 113).

Combining qualitative and quantitative approaches in mixed-methods research yields more accurate and comprehensive information (Canales, 2012). The adoption of mixed methods is driven by the diverse research questions posed in this PhD, which cannot be effectively addressed by a single method alone. Additionally, the approach allows for the validation of data from various sources, including architects in academia, professionals, and students. This process of triangulation strengthens the study by leveraging diverse opinions on the use of immersive technologies in architectural education.

4.4 Methods Used in the PhD Study

Based on the theoretical and methodological foundations explored earlier, this PhD study employs a mixed-methods approach, integrating both qualitative and quantitative data collection methods. The rationale for using this approach lies in the study's complex research questions, which require different perspectives and layers of understanding that cannot be fully addressed by a single method. Mixed-methods research allows for triangulation, enhancing the reliability and validity of the findings by cross-verifying data from multiple sources and methodologies (Creswell & Plano Clark, 2011).

4.4.1 Rationale for Mixed Methods

As outlined by Creswell (2014), mixed-methods research is particularly effective when the research problem requires both exploration and explanation, as it can address "what" and "how" questions simultaneously. This PhD study seeks to explore the effectiveness of immersive technologies in architectural education, as well as explain how these technologies impact learning outcomes, student engagement, and the pedagogical process. By combining qualitative insights with quantitative measurements, this study benefits from a richer and more nuanced understanding of the phenomena under investigation.

For example, the qualitative data obtained from semi-structured interviews with students and educators provide deep insights into the lived experiences and perceptions of immersive technologies in architectural pedagogy. Meanwhile, the quantitative data derived from surveys and statistical analysis offer empirical evidence to support or challenge the qualitative findings (Johnson et al., 2007). This integration of data types helps answer both exploratory and confirmatory research questions in a holistic manner.

4.4.2 Data Sources and Methods of Collection

To gather comprehensive data, this research utilises a combination of interviews, surveys, and case studies, drawing from multiple sources:

Interviews: Semi-structured interviews were conducted with architectural students, educators, and professionals who have experience with immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR). These interviews serve as a critical tool for capturing subjective experiences and personal narratives, providing rich qualitative data (Brinkmann & Kvale, 2015). While a pre-prepared interview guide was used to maintain consistency across participants, the semi-structured format allowed for adaptability in questioning. Follow-up questions were formulated based on three key criteria to ensure both depth and flexibility in participant responses:

1. Clarification & Expansion – If a participant provided a vague or surface-level response, follow-up questions encouraged further elaboration or examples to gain deeper insights.
2. Emergent Themes – When unexpected but relevant topics arose, the interviewer had the flexibility to explore these themes while maintaining alignment with the research objectives.
3. Comparative Inquiry – Participants were asked follow-up questions based on contrasts or similarities with previous responses, helping to identify patterns and variances across different perspectives.

This structured yet flexible approach ensured that the interviews remained focused on key research areas while allowing participants the freedom to articulate their experiences in a way that enriched the study's findings. If no formal criteria had been established, the pre-prepared interview questions were carefully designed to align with the study's core research objectives, ensuring that responses directly addressed themes such as the impact of immersive technologies on spatial cognition, creative design processes, and collaborative learning environments.

Surveys: To complement the qualitative insights from interviews, structured surveys are distributed to a broader cohort of students and educators. The surveys are designed to capture quantitative data on how often immersive technologies are used in architectural education, their perceived effectiveness, and potential barriers to their integration. The Likert-scale format of the surveys allows for measuring degrees of agreement or disagreement, providing a clear framework for statistical analysis (Fowler, 2014).

Case Studies: Case studies of institutions that have already integrated VR and AR into their curricula are also included. These case studies involve a detailed examination of how immersive technologies are used in real-world settings, focusing on pedagogical outcomes, student

engagement, and teaching methodologies. Yin (2018) emphasises the utility of case studies in mixed-methods research, especially when the research aims to investigate contemporary phenomena in depth.

4.4.3 Triangulation and Data Integration

One of the key advantages of mixed-methods research is the ability to triangulate data. By comparing and contrasting the findings from interviews, surveys, and case studies, this study seeks to validate its conclusions through multiple lines of evidence (Patton, 1999). For example, data from interviews may reveal challenges faced by educators when using VR in studio-based teaching, while survey data may quantify how widespread these challenges are across different institutions. The case studies, in turn, provide contextual evidence on how these challenges have been addressed in practice.

The integration of qualitative and quantitative data follows a concurrent triangulation design, in which both types of data are collected and analysed simultaneously rather than sequentially. This approach ensures that findings from one method can be directly compared, validated, or supplemented by insights from the other, allowing for a more comprehensive understanding of the research problem (Creswell & Plano Clark, 2011). By collecting and analysing qualitative and quantitative data in parallel, this study mitigates potential biases inherent in single-method approaches, enhances the validity of findings, and provides a more holistic interpretation of the results. The concurrent nature of this design allows for real-time adjustments and cross-referencing between datasets, ensuring that emerging patterns are triangulated for greater reliability and depth.

4.5 Data Sources and Methods of Collection

This section outlines the primary techniques for collecting data in this study, focusing on surveys, interviews, and observations. As identified by Robson (2002), these methods share common attributes in allowing researchers to gather both qualitative and quantitative information directly

from participants. The survey method, in particular, is chosen for its versatility in collecting data across multiple channels, such as self-completion questionnaires, internet surveys, postal surveys, telephone interviews, and personal contact (Bryman, 2004). In this study, various data collection techniques were employed to ensure a comprehensive understanding of the participants' experiences with immersive technologies in architectural education.

Given the mixed-methods approach of this research, data collection methods were carefully aligned with the research questions, allowing for a detailed examination of the use of Virtual Reality (VR) and Augmented Reality (AR) in architectural education. The following subsections provide an overview of the specific tools and techniques used to collect data, including detailed descriptions of the experiments performed, the tools used, and the rationale for their selection.

4.6 Ethical Considerations

Ethical considerations are paramount in research involving human participants. This study adhered to the University of Nottingham's ethical guidelines, ensuring that participants were fully informed about the study's purpose, procedures, and their rights. Participants were provided with detailed information sheets and consent forms before participating in the experiments. Confidentiality and anonymity were maintained throughout the study, with data stored securely in accordance with GDPR guidelines.

Participants had the right to withdraw from the study at any time without penalty. The study ensured that no physical or psychological harm came to the participants, and appropriate measures were taken to minimize any discomfort, particularly regarding the use of VR and AR technologies.

Key Ethical Protocols Followed:

- **Informed Consent:** Participants were fully informed about the study's objectives, procedures, potential risks, and benefits. Consent was obtained prior to their participation.
- **Confidentiality:** Personal data was anonymized, and all data were stored securely to protect participant privacy.
- **Right to Withdraw:** Participants were informed of their right to withdraw from the study at any point without any negative consequences. (see Appendix for ethics approval documentaion)

4.7 Research Sample and Population

The sample and population are integral components of any research's data collection process (Kothari, 2004). Robson (2002) defines the population of a research involving people as the research population, while the sample represents a subset of the population whose opinions are measured to gather relevant information and data for addressing the research question (Bryman, 2004; Mugo, 2010).

Participants for this study were selected from the University of Kyrenia, Final International University, and Near East University in Cyprus. The selection criteria included undergraduate architecture students and architecture tutors who were willing to participate in the experiments. The recruitment process involved collaboration with faculty representatives who facilitated the identification and invitation of participants.

Sample Size and Characteristics:

- **VR Experiment:** 24 students and 6 tutors from each university, participating in two-week workshops.

- **AR Experiment:** 44 students and 6 tutors from each university, participating in two-week workshops.
- **MR Experiment:** 57 students and 6 tutors from each university participated over an entire semester.

The sample sizes for each experiment were determined based on practical feasibility, prior research, and methodological recommendations for educational technology studies. While there is no universal minimum requirement for immersive technology research in architectural education, similar studies have used sample sizes ranging from 20 to 60 participants per experimental group to ensure meaningful data collection while maintaining logistical feasibility (Lincoln & Guba, 1985; Creswell & Plano Clark, 2011).

For quantitative analyses, the sample sizes were sufficient to conduct descriptive and inferential statistical tests, ensuring reliable trend identification without overextending beyond available institutional resources. The MR experiment, conducted over an entire semester, had a larger sample size to capture longitudinal effects and provide a more comprehensive dataset for iterative design learning.

Although larger sample sizes could enhance generalizability, the current sample sizes align with methodological best practices for mixed-methods research, balancing depth in qualitative analysis with statistical robustness in quantitative assessments (Teddle & Tashakkori, 2009).

Sampling Technique:

- A purposive sampling technique was used to select participants who were most likely to provide valuable insights into the use of immersive technologies in architectural education.

- Participants were selected based on their willingness to engage with new technologies and their availability to participate in the experiments. While this ensured a motivated group of participants, it may have introduced self-selection bias, as students and tutors who were already open to technological innovation may have been overrepresented. To assess whether this impacted the findings, pre-experiment surveys were conducted to measure participants' prior experience and attitudes toward immersive technologies. This allowed for comparisons between participants with differing levels of technological familiarity, ensuring that trends observed were not solely driven by pre-existing enthusiasm or expertise. Additionally, efforts were made to diversify the sample by selecting participants from multiple universities with varied educational approaches. This helped to capture a broader range of perspectives, increasing the generalizability of the results. However, it is acknowledged that the findings may be less reflective of students who are more resistant to adopting new technologies, and future research could explore ways to engage such participants to obtain a more balanced dataset.

4.7.1 Overview of Experiments

The experiments in this PhD study are designed to explore the impact of immersive technologies—Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—on design creativity, communication, and confidence in architectural education. These experiments build upon the theoretical foundations laid out in Chapter 2, which examined the history of architectural pedagogy and the role of technology in shaping architectural education, and Chapter 3, which explored the potential of immersive technologies like VR, AR, and MR in enhancing the learning experience.

In Chapter 2, we highlighted how the evolution of architectural pedagogy has moved toward incorporating digital technologies, emphasizing the need for more interactive, collaborative, and immersive learning experiences (Schön, 1987; Kolb, 1984). This

chapter also identified that modern pedagogical approaches prioritize experiential learning, which promotes learning through doing—an approach that aligns with immersive technology’s ability to offer hands-on, interactive experiences in a virtual or augmented setting.

Chapter 3 further explored how immersive technologies, particularly VR, AR, and MR, are being used across various disciplines and, specifically, in architectural education. The literature reviewed in Chapter 3 (e.g., Dorta et al., 2016; Angulo et al., 2015) emphasized VR’s potential for providing spatial awareness and design feedback, while AR’s real-time interaction and MR’s integrated approach offer new possibilities for collaborative and iterative design development.

The gaps identified in Chapter 3, particularly the need for more research on immersive technologies’ impact on creativity, communication, and confidence, inform the structure of the experiments conducted in Chapter 4. The experiments are designed to address these gaps and extend current research by:

Testing immersive technologies in live architectural studio settings,

Measuring their impact on creativity, communication, and confidence, and

Focusing on specific educational outcomes such as student engagement and competence development.

The experiments directly respond to both the theoretical framework of Chapter 2 and the technological advances discussed in Chapter 3, thereby ensuring a cohesive and justified progression in the research.

4.7.2 Tools Used in Experiments

Before delving into the experiments themselves, it is crucial to provide an introduction to the tools used, including VR, AR, and MR software. These tools were selected based on

their alignment with the pedagogical goals of this study, including fostering creativity, improving communication, enhancing confidence, and developing competence in design.

The primary tool chosen for the VR experiments was Gravity Sketch due to its advanced design capabilities and integration with architectural workflows. Unlike earlier VR tools that were mainly used for post-design visualization, Gravity Sketch allows for real-time design modifications and collaborative sessions, making it an ideal platform for architectural education (Bartosh & Anzalone, 2019). The decision to use Gravity Sketch was based on its ability to align with the pedagogical needs identified in the literature. For instance, research by Abdelhameed (2011) highlights the importance of tools that facilitate creative exploration, while other studies emphasize the need for technologies that support collaboration and real-time feedback (Angulo et al., 2015). Gravity Sketch, with its intuitive interface and real-time collaboration features, addressed these requirements, making it a suitable choice for this research.

In addition to Gravity Sketch, the experiments incorporated Shapr3D and Arkio specifically selected for their unique contributions to Augmented Reality (AR) and Mixed Reality (MR) applications in design.

Shapr3D is an AR-based tool that allows users to interact with 3D models in a real-world context, offering an immersive design experience where students and tutors can manipulate architectural models within the physical environment. This tool was particularly beneficial for design critiques and one-to-one design discussions, as it allowed for immediate feedback and dynamic interaction with models. Shapr3D's AR features provided an important extension of traditional 2D drawings, making abstract concepts tangible and enabling more meaningful discussions on form, scale, and materiality (Sánchez-Sepúlveda et al., 2019).

Arkio was utilized in the Mixed Reality (MR) experiment to combine the immersive qualities of VR with the interactive potential of AR. Arkio enabled students and tutors to collaborate within shared virtual spaces, allowing for real-time collaboration across distances. The platform's cross-device compatibility and ease of integration with other design software made it a powerful tool for conducting collaborative design reviews, offering seamless transitions between AR and VR environments (Gül & Gu, 2019). Arkio was essential for fostering a collaborative learning environment, where participants could interact with complex architectural designs both virtually and physically.

The choice of these tools was also informed by the research presented in Chapter 2, which highlights the need for interactive, experiential learning in architectural education (Schön, 1987). The tools used in this research were selected for their potential to bridge the gap between traditional design methods and the immersive experiences offered by VR, AR, and MR technologies. Each tool offered specific capabilities that aligned with the learning objectives of the study, particularly in terms of enhancing creativity, communication, confidence, and competence—the four key areas this research sought to measure.

By integrating these advanced tools into the experimental design, this research was able to explore how immersive technologies can transform architectural education, providing students with the skills necessary to succeed in an increasingly digital and collaborative professional environment.

4.7.3 VR Experiment

Research Question

This experiment aimed to answer the following research question: How does the use of VR technology, specifically Gravity Sketch, affect students' creativity, communication, and confidence in architectural design? This research question was formulated based on

gaps identified in the literature, particularly regarding the lack of empirical studies that explore the direct impact of VR on student creativity and communication (Abdelhameed, 2011; Campbell & Wells, 2001).

Experiment Design

Participants were introduced to Gravity Sketch through a structured workshop that lasted two weeks. The workshop began with an introductory session to familiarize participants with the VR tools and environments. Following the introduction, participants engaged in hands-on design sessions where they were asked to create and modify architectural models using Gravity Sketch.

Data collection was conducted in two stages: pre-experiment and post-experiment. In the pre-experiment stage, participants were given questionnaires designed to gather baseline data on their perceptions of VR, as well as their initial levels of creativity, communication skills, and confidence. The questionnaires used a Likert-scale format to quantify these perceptions, allowing for quantitative analysis of the data (Fowler, 2014).

In the post-experiment stage, participants were interviewed about their experiences using VR during the workshop. These interviews followed a semi-structured format, allowing participants to express their thoughts and reflections on how VR influenced their design process, creativity, and communication. The qualitative data gathered from the interviews provided rich insights into the participants' experiences, while the quantitative data from the questionnaires allowed for statistical analysis of changes in creativity, communication, and confidence.

Link to Literature:

This experiment builds on existing research that highlights the potential of VR to enhance creative exploration and communication in design settings (Dorta et al., 2016;

Abdelhameed, 2011). While previous studies primarily focused on VR's role in visualization, this experiment explored its impact on the design process itself, providing a more comprehensive understanding of VR's educational potential.

4.7.2 AR Experiment

The AR experiment was designed to explore how Augmented Reality (AR) tools such as Gravity Sketch and Shapr3D can enhance creativity, communication, and confidence in architectural education. This experiment built on the pedagogical principles discussed in Chapter 2, where studio-based learning emphasizes hands-on experimentation and feedback loops. It also aligns with the research discussed in Chapter 3, which highlights AR's potential to enhance design communication by providing real-time feedback and enabling collaborative design critiques.

Research Questions:

The AR experiment aimed to answer the following questions, which were derived from gaps identified in the literature:

How does AR support students' ability to visualize and iterate on their designs in real-time, particularly during the early and middle stages of the design process?

In what ways does AR facilitate communication between students and tutors during design critiques, enhancing the pedagogical dynamics discussed in Chapter 2?

Can AR tools improve students' confidence in presenting and defending their designs, as observed in the findings from Chapter 3 on spatial cognition and design engagement?

Pedagogical Basis:

As discussed in Chapter 3, AR offers unique affordances for interactive learning by overlaying digital elements onto physical spaces, enabling a more engaged and active learning experience. This aligns with Schön's reflective practice model, as the ability to

manipulate 3D models in real-time allows for a more iterative design process, where students reflect on tutor feedback and immediately implement revisions (Schön, 1987). The real-time interaction enabled by AR tools, as highlighted by Martín-Gutiérrez et al. (2015), enhances the experiential nature of architectural education, making it an ideal tool for improving communication and creativity.

Methodology:

The experiment was conducted over two weeks with a cohort of undergraduate architecture students and their tutors. The experiment was structured around one-on-one design sessions, where students used AR tools to present and modify their designs in real-time. Pre-experiment surveys were used to assess participants' baseline familiarity with AR tools, while post-experiment interviews collected qualitative data on their experiences.

The AR tools were chosen for their ability to facilitate collaborative design critiques, as discussed in Chapter 3. Participants were asked to manipulate 3D models of their designs while receiving feedback from tutors, fostering a dynamic and interactive discussion of design decisions.

Tools Used:

Gravity Sketch and Shapr3D were used due to their advanced capabilities in 3D modeling and real-time interaction. These tools support dynamic visualization, allowing participants to adjust their designs based on tutor feedback, thus enhancing creativity and communication.

By integrating AR into studio-based learning, this experiment sought to test how AR could address the communication and iteration challenges outlined in Chapter 2. The real-time

feedback provided by AR tools was anticipated to enhance students' ability to make spatial design decisions, leading to greater confidence and creativity in their design work.

4.7.3 Mixed Reality Experiment

The Mixed Reality (MR) experiment was designed to examine how the integration of both Virtual Reality (VR) and Augmented Reality (AR) technologies in architectural education could enhance students' creativity, communication, and confidence. The study specifically investigated how immersive design processes influenced creative problem-solving, how real-time spatial collaboration improved communication among peers and tutors, and how engaging with virtual prototypes fostered confidence in design decision-making. By combining the fully immersive nature of VR with the contextual layering of AR, MR offered a unique opportunity to explore how these technologies complement each other in supporting iterative design thinking, interactive feedback, and spatial exploration in an educational setting. By combining the immersive qualities of VR with the interactive potential of AR, MR offers a holistic platform where students can engage in iterative design and collaborative learning, supporting the complex demands of modern architectural practice. This experiment builds upon insights from Chapter 2, which discusses the evolution of architectural pedagogy and the increasing importance of digital tools, and Chapter 3, where the educational benefits and challenges of VR and AR are explored.

Research Questions: The MR experiment aimed to address the following questions:

How does the integration of VR and AR within a Mixed Reality environment support creativity and iterative design in architectural education?

Can MR facilitate real-time collaboration and enhance communication between students and tutors during the design process?

To what extent does sustained exposure to MR technologies build confidence and competence in managing complex design tasks?

Justification and Pedagogical Basis: The rationale for adopting MR in this study stems from the theoretical frameworks discussed in Chapter 2 regarding the need for interactive, experiential learning in architecture. Historically, architectural pedagogy has relied on studio-based teaching, where hands-on interaction and immediate feedback drive the creative process (Schön, 1987). As technology advanced, the introduction of CAD and CAAD (discussed in Chapter 2) marked a shift towards digital tools for drafting and visualization. MR builds upon this history by providing real-time interaction with digital models in both virtual and physical spaces, offering more dynamic and integrated learning experiences compared to traditional CAD systems.

In Chapter 3, the potential of VR and AR to transform education was highlighted, particularly in terms of enhancing spatial cognition, collaborative learning, and visualization. MR leverages these benefits by allowing students to transition seamlessly between VR and AR environments, fostering a deeper understanding of spatial relationships while promoting iterative, collaborative design—a core element of architectural education. The educational benefits of MR align with constructivist learning theories, where students actively engage in building knowledge through interaction with their environment (Martín-Gutiérrez et al., 2015).

Methodology: This experiment was conducted over the course of an entire design semester and involved undergraduate architecture students and tutors from multiple universities. The experiment integrated Gravity Sketch, Shapr3D, and Arkio to allow for flexible transitions between VR and AR environments. The participants engaged in weekly

design sessions, where they iteratively developed and refined their designs using MR tools.

The experiment was designed to test how MR could enhance the design process by:

Enabling students to switch between immersive virtual environments (VR) and interactive real-world overlays (AR), supporting creative exploration and real-time feedback.

Encouraging collaborative problem-solving through shared MR environments, where students and tutors could work together on the same digital models.

Data Collection: A combination of qualitative and quantitative methods was used to capture the participants' experiences and performance over the semester. These included:

- Pre-experiment questionnaires to establish baseline data on participants' familiarity with VR, AR, and MR, as well as their initial perceptions of how these technologies might impact their design process.
- Weekly observation sessions and shadowing to document how participants engaged with MR technologies during studio sessions. Observations focused on the flow of communication, the iterative design process, and the participants' ability to solve design problems collaboratively.
- Post-experiment interviews conducted at the end of the semester, where participants were asked about their experiences with MR tools, focusing on how MR supported creativity, communication, and confidence.
- Mid-semester and final questionnaires were administered to track changes in students' perceptions of MR's educational value and its impact on their design outcomes.

Tools Used:

Gravity Sketch: Provided an intuitive VR environment for 3D design exploration, allowing students to create complex models and interact with them in an immersive space.

Shapr3D: Offered an AR tool for real-time manipulation of 3D models, enabling students to view and modify designs within a physical context.

Arkio: Facilitated collaborative MR sessions, where both tutors and students could interact with the same digital model in shared virtual and physical spaces, enhancing communication and collaboration.

Link to Literature: This experiment builds on the findings from Chapter 3, where both VR and AR were shown to have distinct advantages in architectural education. For example, VR has been found to enhance creativity by allowing students to experience their designs, gaining spatial insights that are difficult to achieve with 2D drawings (Angulo et al., 2015). Similarly, AR has been noted for its ability to enhance communication by overlaying digital elements onto physical models, facilitating more dynamic design discussions (Sánchez-Sepúlveda et al., 2019). By integrating both technologies into a single platform, MR addresses the limitations identified in earlier research, providing a more comprehensive design environment.

In addition, this experiment addresses a gap in the literature by exploring MR's long-term impact on confidence and competence in handling advanced design tools. While studies like those by Huang et al. (2018) and Zhang et al. (2018) have examined the short-term effects of immersive technologies on creativity and spatial understanding, the current research offers a more extended investigation, tracking participants' progress over an entire semester to assess how continuous engagement with MR influences their design skills and professional development.

4.8 Data Analysis

The data collected from the experiments were analyzed using both descriptive statistical methods and thematic analysis to provide a comprehensive understanding of how immersive technologies influence architectural education. The data analysis approach varied slightly between the VR, AR, and MR experiments, but adhered to consistent principles in analyzing creativity, communication, confidence, and competence across all experiments.

Quantitative Data Analysis

The quantitative data from the questionnaires, which primarily used Likert scales, were analyzed using non-parametric statistical methods due to the ordinal nature of Likert data (Boone & Boone, 2012). Descriptive statistics—including means, standard deviations, and frequencies—were calculated to establish baseline comparisons and identify trends in students' creativity, communication, and confidence levels before and after the experiments (Bryman, 2012).

For the VR experiment, participants' self-reported confidence, communication, and creativity were evaluated using the Wilcoxon signed-rank test, which assessed changes between pre- and post-experiment scores (Pallant, 2016).

For the AR experiment, the same non-parametric analysis was used to evaluate changes in participants' spatial reasoning and real-time design feedback capabilities.

For the MR experiment, the emphasis was placed on participants' ability to transition between VR and AR environments seamlessly, with pre- and post-experiment scores capturing their perceptions of creativity, communication, and design confidence.

Qualitative Data Analysis

The qualitative data from interviews and observation sessions were analyzed using thematic analysis, as described by Braun & Clarke (2006). This process involved coding interview

transcripts to identify recurring patterns and themes, such as the development of creativity, communication efficacy, and increased confidence in immersive settings.

For the VR experiment, thematic analysis focused on the participants' engagement with spatial immersion and the tools' role in fostering more innovative design ideas (Clarke & Braun, 2017).

For the AR experiment, the qualitative data revealed themes related to improved design communication between students and tutors through the ability to interact with 3D models in real-time (Creswell & Poth, 2018).

For the MR experiment, the analysis emphasized how MR facilitated collaboration and fostered iterative feedback in design discussions. Emerging themes highlighted the fluidity of switching between AR and VR environments, which was seen as beneficial for creativity and problem-solving.

To enhance the validity and reliability of the findings, triangulation was applied by combining and comparing quantitative and qualitative data (Patton, 2002):

For the VR experiment, confidence and creativity were measured using a Likert-scale self-assessment survey (ranging from 1 to 5), alongside tutor evaluations based on predefined creativity assessment rubrics (e.g., originality, spatial complexity, and innovative problem-solving metrics). These quantitative results were cross-referenced with qualitative insights gathered through semi-structured interviews and observational data on students' immersive experiences in design.

For the AR experiment, communication improvements were assessed through peer-reviewed collaboration scores, structured observational coding (e.g., clarity of verbal and visual communication in real-time design discussions), and self-reported effectiveness ratings on AR-mediated interactions. These were matched against qualitative feedback on how AR influenced real-time collaborative design processes.

For the MR experiment, creativity scores were quantified using pre- and post-experiment creativity assessments based on the Consensual Assessment Technique (CAT) and task-based performance scoring. These results were triangulated with students' subjective experiences, reflective journals, and tutor feedback on iterative design engagement.

By integrating these measurement techniques, the triangulation process ensured that the study's findings were not solely reliant on self-reported perceptions but also incorporated structured evaluations and observational insights for a more comprehensive understanding of the impact of immersive technologies in architectural education.

Each experiment's methodology and analysis were self-contained to provide clarity and precision in addressing the study's research questions and hypotheses.

4.9 Research Methods Not Adopted

While the adoption of a mixed-methods approach offers significant advantages by complementing the strengths and mitigating the limitations of qualitative and quantitative methods, it does not entirely negate the challenges associated with each method. Notably, this study chose not to adopt focus groups or direct observation methods due to several practical and methodological concerns.

4.9.1 Focus Groups

Focus groups involve pre-arranged meetings of target participants to discuss specific topics in-depth. They can provide rich qualitative data through group interactions and discussions. However, several limitations influenced the decision to exclude focus groups from this study:

- **Logistical Challenges:** Coordinating a time and place for multiple participants to gather can be difficult, especially when participants are spread across different geographical locations and have varied schedules (Morgan, 1997).

- **Cost Considerations:** Convening a focus group often involves significant costs, including travel expenses, venue hire, and compensation for participants' time, which can be prohibitive (Krueger & Casey, 2014).
- **Participant Dynamics:** The dynamics of group interactions can sometimes lead to dominant voices overshadowing quieter participants, potentially skewing the data. There is also a risk of groupthink, where participants may conform to the dominant opinion rather than expressing their true views (Barbour, 2007).

Given these challenges, the decision was made to use individual interviews and surveys to gather qualitative data, ensuring a more controlled and comprehensive collection of insights.

4.9.2 Direct Observation

In this research, direct observation was employed to gather insights into how participants interacted with VR and AR systems in a natural, non-intrusive manner. While the researcher was present during the sessions, their involvement was minimal to avoid influencing participants' behavior. The focus was on observing natural interactions with the technology, without direct interference in the design processes or discussions.

Key Aspects of Direct Observation:

Non-Interference: The researcher only intervened to resolve technical issues related to hardware or software, ensuring that participants' focus remained on their tasks without interruptions. This approach helped avoid contaminating the data while still enabling observation of meaningful interactions.

Ethical Considerations: Unlike covert observation, all participants were fully informed about the research process, and consent was obtained in advance. Participants were

aware that the researcher would be present but were assured that they would not be actively observed or critiqued during the design process (Robson, 2011).

Minimizing Observer Bias: To minimize observer bias and reduce the Hawthorne effect—where participants may alter their behavior due to the researcher's presence—efforts were made to shift the researcher's role toward resolving technical issues rather than closely monitoring participants' actions. This approach helped reduce the likelihood of participants modifying their natural behavior (McCambridge et al., 2014).
Resource Management: While direct observation is resource-intensive, the non-intrusive nature of this study allowed for periodic observations that captured participants' natural engagement with VR and AR tools, without requiring continuous monitoring (Yin, 2018).

Rationale for Limited Observation:

Given the nature of this research, non-intrusive direct observation was deemed more appropriate than traditional, continuous observation methods. The focus was on gathering data through interviews, surveys, and digital tracking tools embedded in the VR and AR systems, which provided comprehensive feedback on participants' interactions with immersive technologies.

4.10 Methodological Limitations

Despite the strengths of a mixed-methods approach, several methodological limitations were encountered during the research process. Understanding these limitations is crucial for interpreting the findings and considering areas for future research.

Overlapping Data Collection Methods

The use of both qualitative and quantitative data collection methods can sometimes lead to redundancy. For instance, similar questions may appear in both surveys and interviews, which can confuse participants and potentially lead to inconsistent responses. Efforts were made to

streamline the data collection instruments to minimize overlap while ensuring comprehensive coverage of research topics (Teddle & Tashakkori, 2009).

Participant Bias:

There is always a risk of bias in participants' responses, whether due to social desirability, where participants provide answers they believe are expected or acceptable, or due to misunderstandings of the questions posed. To mitigate this, questions were carefully designed to be clear and neutral, and participants were assured of the confidentiality and anonymity of their responses (Bryman, 2016).

Human Error:

Human error can occur at various stages of the research process, from data collection to analysis. Misinterpretations of participants' responses or errors in data entry can impact the validity of the findings. To address this, multiple data verification steps were implemented, including cross-checking by different team members and using software tools for data analysis to reduce the risk of errors (Creswell, 2014).

Technical Limitations:

The reliance on advanced technologies such as VR and AR introduces specific technical limitations. These include potential hardware malfunctions, software bugs, and the steep learning curve associated with using these technologies. Comprehensive training sessions were conducted to familiarize participants with the technology and minimize technical issues during the data collection process (Billinghurst & Duenser, 2012).

Generalizability:

The findings from this research may have limited generalizability beyond the specific context of the universities involved. The unique characteristics of the sample population, including their familiarity with digital tools and architectural education practices in Cyprus, may not reflect

broader populations. Future studies could expand the sample size and diversity to enhance the generalizability of the results (Maxwell, 2013).

By acknowledging these limitations, the research process remains transparent, and the findings can be interpreted with an understanding of the potential constraints. Future research should aim to address these limitations to build on the insights gained from this study.

4.11 Chapter Summary

Chapter 4 has delineated the research methodology embraced in this thesis, elucidating the philosophical underpinnings guiding the research. It became evident that the research thesis adopts a pragmatic viewpoint, with the selection of a mixed-methods approach bolstering the rationale behind the chosen methodology. The primary aim of employing a mixed-methods approach was to corroborate and validate the findings obtained from other methods utilized (Maxwell, 2005). To substantiate this research approach and design, various data sources were utilized, aiming to capture the perceptions of design professionals in Cyprus regarding the research subject matter. The principal sources included the questionnaire survey tool and case study modeling, both furnishing comprehensive information and data pivotal for achieving the research aim. The chapter culminates in addressing potential limitations of the research methodology and delineates how the researcher navigated ethical considerations to ensure adherence to the standards of the University of Nottingham. Subsequently, Chapter five delves into a detailed analysis of the data gleaned from both questionnaire surveys and interviews, alongside outlining the outcomes of the fieldwork. Chapter six subsequently unfolds, presenting two case studies that model both traditional architecture and contemporary architecture examples.

Chapter 5: VR Experiment

5.1 Experiment 1: Virtual Reality (VR) Workshop

Overview

This chapter introduces the first of three immersive technology experiments conducted as part of this research, focusing on the use of Virtual Reality (VR) in architectural education. The workshop was designed as a pilot study to explore the preliminary impact of VR on architectural design processes and to refine both the methodological framework and research instruments for the subsequent Augmented Reality (AR) and Mixed Reality (MR) experiments.

The core aim of this pilot was to evaluate the extent to which immersive modelling using VR tools such as Gravity Sketch could enhance students' creativity, communication, and confidence in architectural design education. By allowing students to conceptualise and experience spatial ideas at full scale, this experiment investigated the pedagogical value of VR as more than a visualisation tool—specifically, as a medium for iterative design and collaboration.

The experiment was informed by prior literature that highlights the educational benefits of immersive design tools. Studies such as Whyte & Nikolić (2018) and Abdelhameed (2011) have demonstrated how VR can support real-time feedback, enhance spatial cognition, and enable reflective design practices. This pilot experiment was therefore structured to examine these affordances within the context of a short, intensive design task—providing a foundation for comparing and expanding immersive strategies in subsequent AR and MR experiments.

This chapter presents the first experimental study, which explores the integration of Virtual Reality (VR) into architectural education. The experiment aimed to investigate the impact of immersive technologies on students' creativity, communication, and confidence during the early stages of the architectural design process. This study aligns with the broader research objectives outlined in Chapter 1 and builds on the theoretical frameworks discussed in Chapters 2 and 3,

particularly Schön's concept of reflective practice and constructivist learning approaches (Schön, 1987; Oxman, 2008).

The experiment was structured as a short workshop using Gravity Sketch on Oculus Quest 2 headsets and was conducted across three universities: the University of Nicosia, the University of Kyrenia, and Near East University. The primary research questions addressed in this phase included:

- How does the use of VR influence students' creative output and spatial reasoning?
- Can VR improve communication between students and tutors during design critique sessions?
- What role does VR play in developing students' confidence in presenting their ideas?

The methods used were inspired by previous research into immersive learning environments (e.g. Abdelhameed, 2011; Whyte & Nikolić, 2018), which demonstrated the potential of VR to enhance architectural design exploration. However, unlike prior studies that often focused on late-stage walkthroughs, this experiment deliberately integrated VR from the beginning of the design process to assess its value as a generative design tool.

Executive Summary of the Workshop Design

The VR workshop tasked students with designing a small architectural pavilion over three days. The brief was calibrated to suit their educational level and was structured to leverage the unique affordances of immersive modelling:

- Emphasis on exploring parametric forms and spatial experimentation.
- Real-time iterative modelling and feedback using immersive walkthroughs.
- Collaboration in small teams, supported by live tutor reviews.

Tools and Outputs:

- Hardware: Oculus Quest 2 headsets and stylus controllers.
- Software: Gravity Sketch (primary), Rhino (post-processing), Zoom (for discussions).

- Design Outcomes: Pavilion models ranged from organic, fluid geometries to function-driven modular forms. Students engaged in iterative design, spatial immersion, and collaborative critique, leading to diverse and innovative solutions.

- 5.1.1 Executive Summary of the VR Pilot Experiment.

This chapter presents the findings of a pilot study conducted to assess the application of Virtual Reality (VR) in architectural education. The pilot served as a foundational exercise to inform the development and refinement of subsequent experiments involving Augmented Reality (AR) and Mixed Reality (MR). Conducted as a three-day design sprint, the workshop invited second- and third-year undergraduate architecture students from the University of Nicosia, University of Kyrenia, and Near East University to explore immersive design processes using Gravity Sketch via Oculus Quest 2 headsets.

Objectives & Methodological Context:

The primary aim of the pilot experiment was to evaluate the effectiveness of immersive design environments on student creativity, spatial understanding, and communication. The research questions focused on whether VR could:

- Enhance spatial perception and iteration in early-stage design.
- Support more engaging and intuitive design presentations.
- Be integrated into studio pedagogy with meaningful educational outcomes.

The experiment built upon findings from prior studies such as Abdelhameed (2011) and Whyte & Nikolić (2018), who emphasized the cognitive and spatial learning potential of immersive tools in architectural pedagogy.

Experiment Structure and Design Brief:

The task brief challenged students to design a small architectural pavilion emphasizing:

- Organic and parametric design exploration.
- Real-time iteration and spatial testing within immersive environments.
- Collaborative critique and presentation using VR walkthroughs.

This structure ensured the task matched the participants' skill levels while leveraging the capabilities of VR for creative experimentation.

Equipment Used:

- Hardware: Oculus Quest 2 headsets, stylus controllers, and desktop stations.
- Software: Gravity Sketch (VR modelling), Rhino (post-processing), Zoom (feedback sessions).

Tutor Assessment and Feedback:

Tutors compared VR-generated student work with traditional CAD submissions and observed:

- Improved spatial awareness and creative fluency in VR models.
- Greater ease in iterative design exploration.
- Difficulties with technical detailing and dimensional accuracy.
- Overall, the work was assessed as mid-to-high grade in creativity, with room for refinement in technical execution.

Quantitative and Qualitative Data Integration:

The pre- and post-experiment questionnaires and semi-structured interviews worked in tandem:

- Pre-surveys gauged baseline digital proficiency and expectations.
- Post-surveys measured changes in perceived creativity, communication, and confidence.
- Interviews provided deeper insights into the participants' experience with VR as a design tool.

This triangulated approach enabled a robust evaluation of the pilot's outcomes and directly influenced the design of the following AR and MR experiments.

5.2 Introduction to VR Experiment

Virtual Reality (VR) technology has revolutionized how architecture is taught and learned by immersing students in interactive design environments that traditional two-

dimensional representations, such as blueprints or CAD renderings, cannot match. As architectural education increasingly moves toward integrating digital tools, VR is seen as a platform that offers not just visualization but also spatial comprehension, experiential learning, and collaborative capabilities. The immersive nature of VR allows students to engage with design spaces in ways that resemble the final physical reality, offering unprecedented opportunities to refine architectural pedagogy.

In Chapters 2 and 3, we discussed the evolution of digital tools in architectural education, tracing the history of Computer-Aided Architectural Design (CAAD) and its eventual integration into design curricula. As highlighted, CAAD tools initially functioned as secondary aids to hand-drawing but have become central to the architectural design process over the last two decades. However, while CAAD allows architects to explore complex forms and create more accurate models, it still operates primarily in a two-dimensional space on a computer screen. The introduction of VR provides a platform that allows students to experience and manipulate designs three-dimensionally, adding another dimension to both design exploration and architectural pedagogy.

VR tools like Gravity Sketch can simulate real-world spatial conditions, making them more than just visualization aids—they enable full spatial immersion, allowing users to interact with designs as though physically present within them. While both VR and traditional screen-based CAD tools allow for real-time modification, VR’s embodied experience differentiates it by offering:

- Depth perception and scale awareness: Unlike a screen-based 3D model, which limits perception to a fixed viewpoint, VR enables users to physically move

through and experience spaces at a 1:1 scale, fostering a stronger spatial understanding.

- Intuitive spatial interaction: Manipulating objects in a 3D immersive space with motion controllers differs from modifying designs via a 2D screen and mouse, as it mimics real-world interactions.
- Cognitive engagement with space: The ability to occupy and dynamically navigate the space enhances the reflective design process, as theorized by Schön (1987).

While real-time design modification is possible in both VR and screen-based modeling, VR introduces a cognitive shift, where design decisions are informed by an experiential rather than a representational understanding of space. This aligns with constructivist learning theories (Oxman, 2008), which emphasize learning through direct interaction rather than passive observation.

This experiment builds on these theories by investigating how VR, as a design tool, impacts architectural students' ability to think creatively, communicate design ideas, and gain confidence in their designs. Through an empirical approach, this study seeks to understand how immersive technologies can be integrated into the existing design studio, potentially transforming how architectural education is delivered.

5.3 Theoretical Context:

VR as a pedagogical tool aligns with the growing body of research on immersive learning, which emphasizes the role of interactive, real-time environments in improving student engagement and learning outcomes (Freina & Ott, 2015). Immersive learning environments foster deeper cognitive engagement, as they allow students to not only visualize but also "experience" their designs as if they were physically present within

them. This study addresses gaps in existing research, specifically the need to understand how VR can enhance the iterative design process, improve communication between students and tutors, and foster confidence in presenting complex design ideas.

5.4 Research Aims and Questions

Research Aims:

- To assess whether VR enhances students' creative capacity by providing an environment that encourages experimentation and real-time modifications.
- To determine if VR improves the communication process in design critiques by allowing for more intuitive, shared experiences between students and tutors.
- To evaluate whether VR increases students' confidence in presenting and defending their designs by offering a more tangible, immersive understanding of their work.

This VR experiment was designed to address several key research questions, focusing on the broader impact of immersive technologies on architectural education, specifically creativity, communication, and confidence. These questions arise from the theoretical frameworks discussed in previous chapters, which emphasize reflective practice, cognitive engagement, and collaborative learning in design education.

Primary Research Questions:

1. How does the use of VR affect students' creativity during the architectural design process?

In traditional design education, creativity is often assessed through the iterative refinement of ideas, where students develop concepts based on feedback from tutors and peers (Milovanovic et al., 2017). This process is influenced by established design norms, cultural conventions, and pedagogical expectations, raising the question: To what extent is spatial appreciation an innate skill versus a learned behavior shaped by architectural education?

While spatial understanding has inherent cognitive components—such as depth perception and visual memory—much of what is considered "creative" in architecture is socially constructed, informed by historical precedents, tutor feedback, and institutional frameworks. VR provides a unique opportunity to test this dynamic, as it allows students to engage with space experientially rather than representationally (Radianti et al., 2020).

Unlike traditional 2D sketching or CAD modeling, which rely on abstract representations, VR facilitates direct spatial engagement, where students can:

- Experiment with scale, proportion, and form in real-time, reinforcing intuitive spatial thinking.
- Break away from conventional representational constraints by immersing themselves within their designs, fostering more organic and exploratory workflows.
- Challenge ingrained design norms by allowing for embodied interaction, making creativity less reliant on predefined architectural conventions and more on spatial experience.

This question investigates whether VR's experiential nature enhances creative exploration, enabling students to test spatial relationships, forms, and materials in a way that traditional methods—bound by screens, sketches, or static models—cannot fully replicate. If creativity in architecture is partly learned through social exposure to design norms, VR may provide a way to disrupt or expand these norms by offering alternative ways of engaging with space that are less constrained by historical precedents (Wang & Schnabel, 2019).

2. Does VR facilitate better communication between students and tutors in architectural education?

Communication between students and tutors is central to the learning process, particularly in architecture, where complex spatial ideas must be conveyed. Traditional methods of communication, such as sketches and CAD models, often limit the ability to fully articulate three-dimensional spatial concepts (Alizadehsalehi et al., 2019; Aydın & Aktaş, 2020). This question explores whether VR can enhance communication by allowing students and tutors to co-experience designs in a shared virtual space, fostering more productive critiques and feedback (Goldschmidt et al., 2010; Beier, 2014).

3. To what extent does VR improve students' confidence in presenting and defending their designs?

Confidence in architectural presentations is often built through a thorough understanding of spatial, functional, and aesthetic aspects of one's design. VR supports this by offering immersive walkthroughs that give students a full-scale

experience of their own creations, thereby reinforcing their ability to articulate and defend design decisions (Paes et al., 2017; Liu et al., 2020). Prior research and experimental data have shown that students report greater ease and assurance when explaining spatial intent in VR environments compared to static models or 2D screens (Lang & Hovestadt, 2003; Veisz et al., 2012).

By answering these questions, the study seeks to contribute to the growing body of knowledge on immersive technologies in architectural education, providing empirical evidence of VR's potential to transform design pedagogy. The results of this study could inform future curriculum development, integrating VR as a core tool for teaching architectural design.

5.5 Pre experiment Results Analysis for VR (Virtual Reality) Workshop

5.5.1 Pre-Experiment Setup and Tools

5.5.1.1 Tools and Software Overview

As outlined in Chapter 4, the VR experiment utilized Gravity Sketch as the primary design tool. This decision was based on its unique capabilities as both a creative and collaborative platform, aligning well with the educational goals of this study. Gravity Sketch allows for real-time design modifications, enabling students to experience their designs as three-dimensional objects in an immersive environment. It supports a range of architectural workflows, including freehand sketching, modeling, and precise geometric construction, making it versatile for both early conceptual design and more refined stages.

The integration of VR into architectural education, as discussed in Chapter 2, is not new, but previous implementations often faced technical limitations, such as complex model

exportation processes and the lack of interactive features (Dorta et al., 2016). Gravity Sketch addresses these limitations by offering a seamless workflow that enables students to design directly within the VR environment, thus avoiding the disruptive exportation steps found in earlier VR platforms (Bartosh & Anzalone, 2019).

5.5.1.2 Rationale for Choosing Gravity Sketch

Several factors influenced the decision to use Gravity Sketch in this experiment. As highlighted by Abdelhameed (2011), VR tools must facilitate creative exploration without overwhelming the user with technical complexity. Gravity Sketch provides an intuitive user interface that encourages creative freedom while offering advanced design capabilities suited to architectural education. This aligns with Schön's (1987) concept of reflective practice, where the design process involves continuous reflection and iteration. The platform's collaborative features, such as co-creation capabilities, also allow for real-time feedback, which is critical in architectural design education (Angulo et al., 2015).

Moreover, research by Oxman (2008) emphasizes the importance of constructivist learning environments in fostering creativity and innovation. Gravity Sketch's immersive environment promotes an active learning approach by allowing students to engage directly with their designs, test their ideas in real time, and make adjustments based on spatial awareness and feedback. These features support the development of cognitive skills essential for architectural design, such as spatial reasoning, problem-solving, and aesthetic judgment.

5.5.1.3 Experiment Setup

The experiment took place over a two-week workshop period, where students and tutors engaged in multiple design sessions using VR technology. The workshop was conducted in a design studio environment, allowing for a seamless transition between traditional design tools (e.g., sketches and CAD models) and VR tools. The studio was equipped with HTC Vive Pro and Oculus Quest 2 headsets, which were chosen for their high-resolution displays and precision tracking, ensuring an immersive and responsive experience.



Image 5.5.1 HTC Vive Pro VR headset used for the VR experiment.



Image 5.5.2 Oculus Quest VR headset used for the VR experiment.

Before the experiment began, participants received a comprehensive introduction to the VR tools and hardware, including tutorials on how to navigate the VR environment and use Gravity Sketch's features. This preparatory phase was essential in mitigating the challenges highlighted in earlier studies, where participants struggled with the initial learning curve of VR tools (Freina & Ott, 2015). By ensuring that students and tutors were comfortable with the technology, the experiment aimed to minimize technical disruptions and focus on the pedagogical impact of VR on creativity, communication, and confidence.

5.5.1.4 Participants and Sample Group

The participants included 24 undergraduate architecture students and 6 tutors, from three universities around Cyprus. The students were in their second and third years of study, ensuring that they had foundational knowledge in architectural design but varying levels of experience with digital tools. The selection of second- and third-year students is significant because, as discussed in Chapter 2, first-year students often struggle with CAD-based tools, and more immersive technologies like VR and AR are better suited for students with intermediate experience (Oxman, 2008).

The tutors involved in the experiment were experienced architects and educators, familiar with traditional and digital design tools. Their role was to provide feedback during the design sessions and to participate in post-experiment interviews to assess the impact of VR on design communication and critique processes.

5.5.2 Data Collection

Data collection for the VR experiment employed a mixed-method approach, combining quantitative surveys and qualitative interviews. This approach was designed to capture both the measurable outcomes (e.g., improvements in creativity, communication, and confidence) and the subjective experiences of the participants, aligning with the theoretical frameworks of mixed-method research discussed in Chapter 4 (Johnson & Onwuegbuzie, 2007).

5.5.3 Pre-Experiment Questionnaires

Before the VR workshop, participants completed a pre-experiment questionnaire to establish a baseline for their familiarity with VR technology and their self-assessed creativity, communication skills, and confidence in presenting architectural designs. The questionnaire consisted of Likert-scale questions, allowing for the quantitative measurement of these factors.

To effectively assess the integration of immersive technologies in architectural education, the questionnaire was designed to gather baseline data on participants' prior experiences with digital tools—particularly CAD and CAAD. This set of questions evaluates the frequency and depth of digital tool usage in coursework, aiming to determine whether students and tutors have sufficient familiarity and competence with digital workflows to support the adoption of VR. Understanding participants' engagement with CAAD provides context for interpreting their readiness to transition to immersive environments and the potential barriers or enablers of that transition.

The data collected from the Likert-scale responses were analyzed using non-parametric statistical methods, specifically the Wilcoxon Signed-Rank Test and Kruskal-Wallis Test, due to the ordinal nature of the data and the relatively small sample size. These tests were selected because:

1. Likert data are not normally distributed, violating the assumptions required for parametric tests such as t-tests;
- The study required comparison of pre- and post-experiment results to assess shifts in creativity, confidence, and communication;
- Group comparisons (e.g. between students and tutors) required methods that do not assume equal variance.

As an illustrative example, a Wilcoxon Signed-Rank Test comparing students' self-reported creativity before and after the VR workshop indicated a statistically significant improvement ($Z = -2.87$, $p = 0.004$), suggesting that the immersive experience enhanced their ability to develop and articulate creative ideas. Similar analyses were conducted for communication and confidence, with detailed results presented in 5.8.4 Summary of Comparative Analysis.

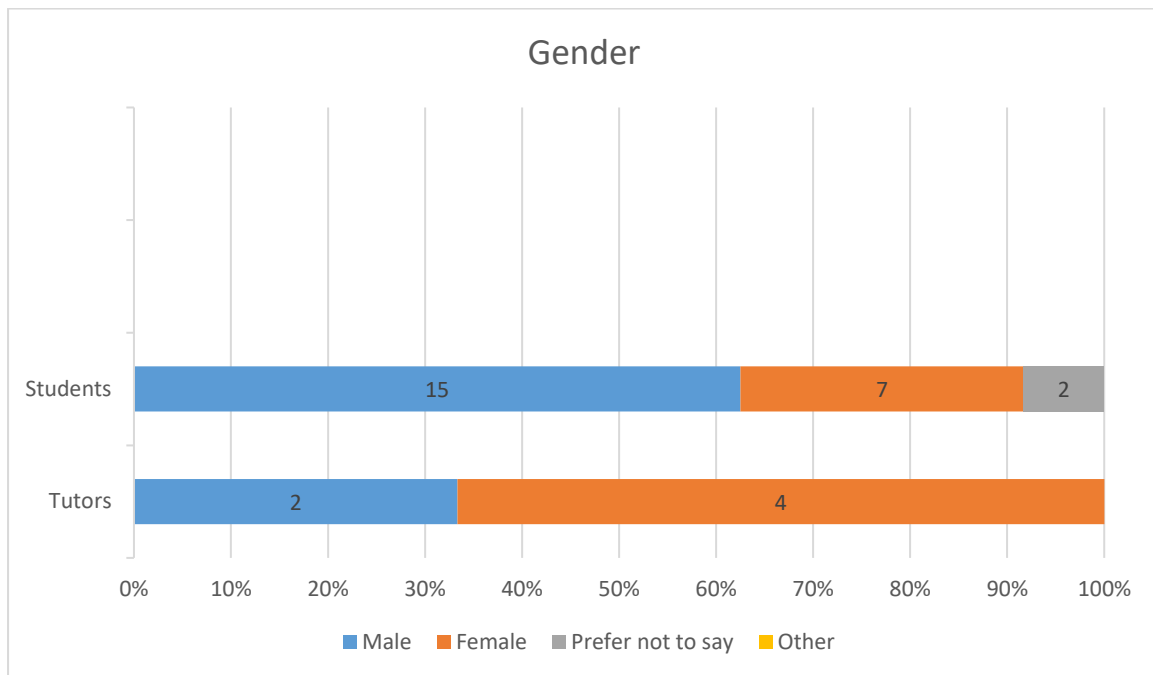
These analytical methods align with the statistical approach outlined earlier in the document, ensuring consistency in the way quantitative results were handled throughout the study. The choice of non-parametric analysis allowed for a more robust interpretation of ordinal data, reducing the risk of misrepresenting participant responses due to inappropriate statistical assumptions.

Participants were asked to rate their level of agreement with statements such as:

- I feel confident presenting my architectural designs to a group.
- I find it easy to communicate complex design ideas visually and verbally.
- I am familiar with using immersive technologies in design processes.

The results from these Likert-scale responses provided the foundation for subsequent comparative analyses, helping to track the impact of the VR workshop on student and tutor perceptions over time. This baseline data was essential for comparing participants' perceptions and abilities before and after the VR workshop. Similar pre-experiment questionnaires have been used in previous studies to assess the impact of immersive technologies on students' learning experiences (Freina & Ott, 2015; Radi et al., 2021).

Figure 5.5.3.1 Gender Distribution



Source: Compiled by the author (2022)

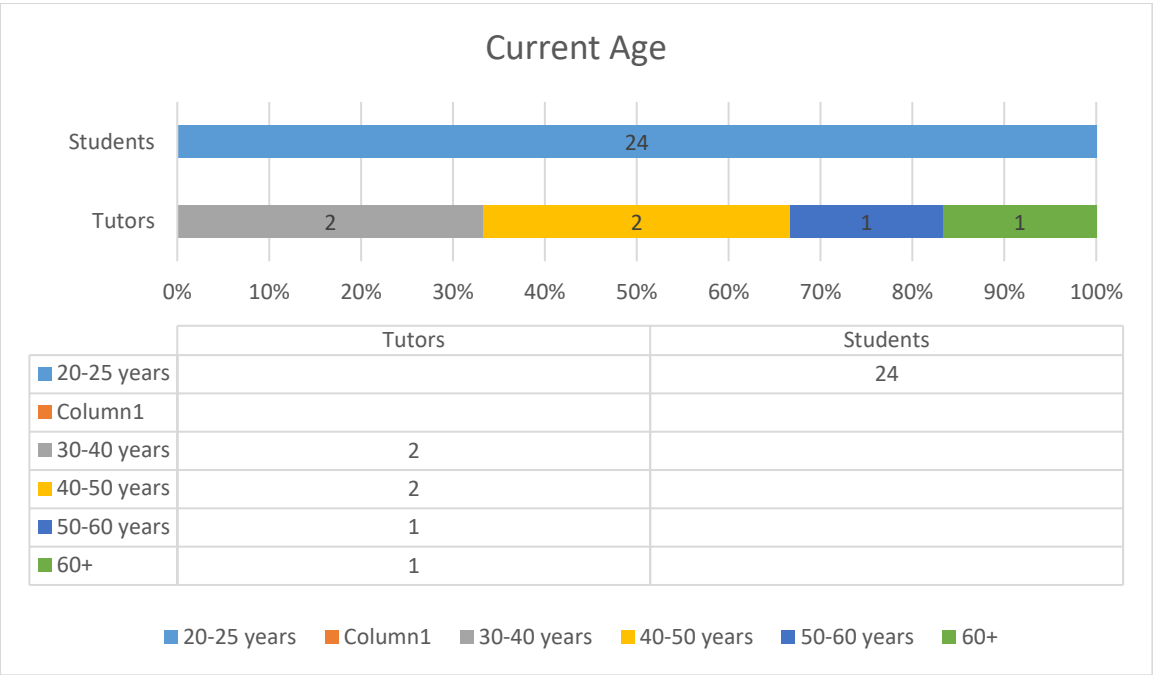
Analysis: The gender distribution among tutors is relatively balanced, while the student cohort exhibits a higher proportion of males. This pattern is consistent with historical gender imbalances in architectural education (Caven & Diop, 2017). However, at the University of Nicosia (UoN), recent enrollment statistics indicate a more balanced gender distribution among architecture students. The skew toward male students in this sample suggests that our participant group may not be fully representative of the broader student population at University of Nicosia, which should be considered when generalizing findings.

Understanding gender distribution is relevant when addressing specific learning needs and engagement levels during VR workshops. Studies suggest that male and female students may engage differently with digital tools and immersive technologies (Schell et al., 2018). For

example, male students have been shown to demonstrate greater initial confidence in adopting new digital tools, whereas female students often excel in collaborative environments and reflective tasks once initial familiarity is established (Cooper, 2006). These differences may influence how each group interacts with VR platforms, such as the degree of initiative taken in spatial experimentation or preference for guided versus exploratory learning. Therefore, acknowledging these tendencies can help in tailoring instructional approaches to ensure equitable participation and support for all learners.

Additionally, a balanced representation among tutors contributes to a broader range of perspectives and pedagogical approaches. Research on architectural education indicates that diversity within teaching teams—whether in terms of gender, cultural background, professional experience, or design philosophy—can foster more inclusive discussions, encourage varied problem-solving strategies, and help mitigate potential biases in feedback (Donnelly & Diaz, 2020). In the context of VR workshops, this diversity ensures that students are exposed to multiple interpretations of spatial design, differing critique styles, and alternative workflows, ultimately enriching the learning environment and supporting deeper engagement across a wider range of learners.

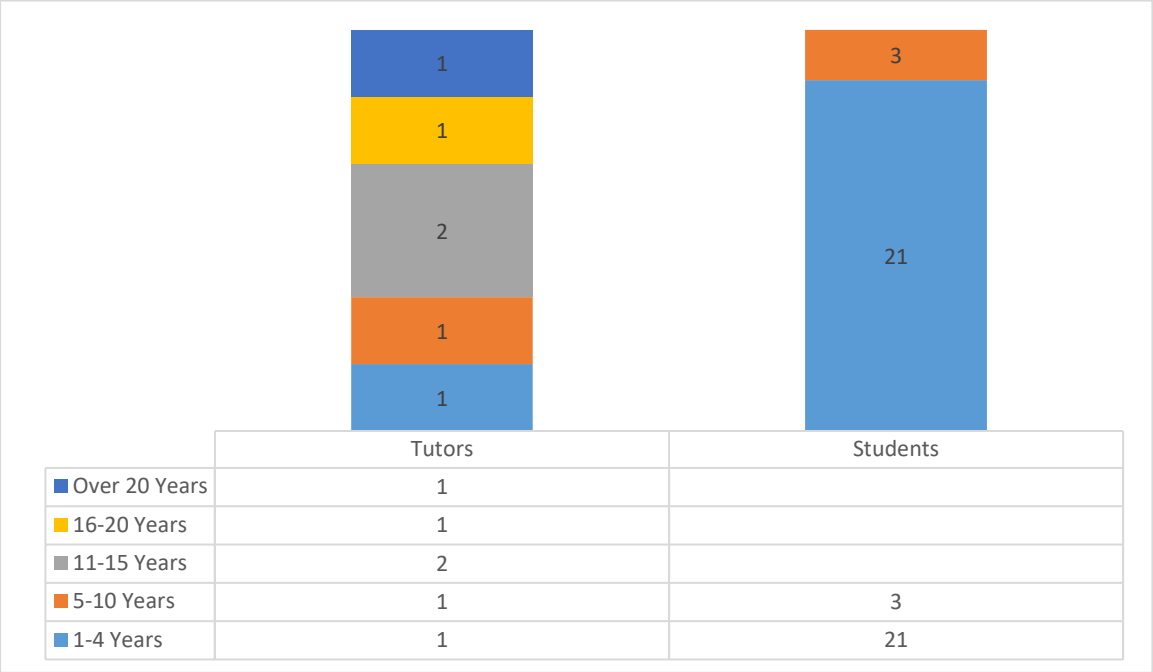
Figure 5.5.3.2 Age of the Respondents.



Source: Compiled by the author (2022)

Analysis: The diverse age range among tutors, from 30 to over 60, brings a wealth of professional experience and pedagogical perspectives to the VR workshops, contributing to a richer and more nuanced learning environment for students. In contrast, the students—primarily aged 20 to 25—are in the formative stages of their architectural education, which is typical of undergraduate cohorts. This age contrast fosters an intergenerational exchange of knowledge, where experienced practitioners can offer mentorship and critical insights, while younger students may introduce fresh digital fluency and experimentation. Research suggests that such intergenerational learning environments can enhance collaborative learning, support adaptive teaching methods, and improve students’ ability to contextualize emerging technologies within broader professional practices (Billett, 2014; Duffy & Jonassen, 2013).

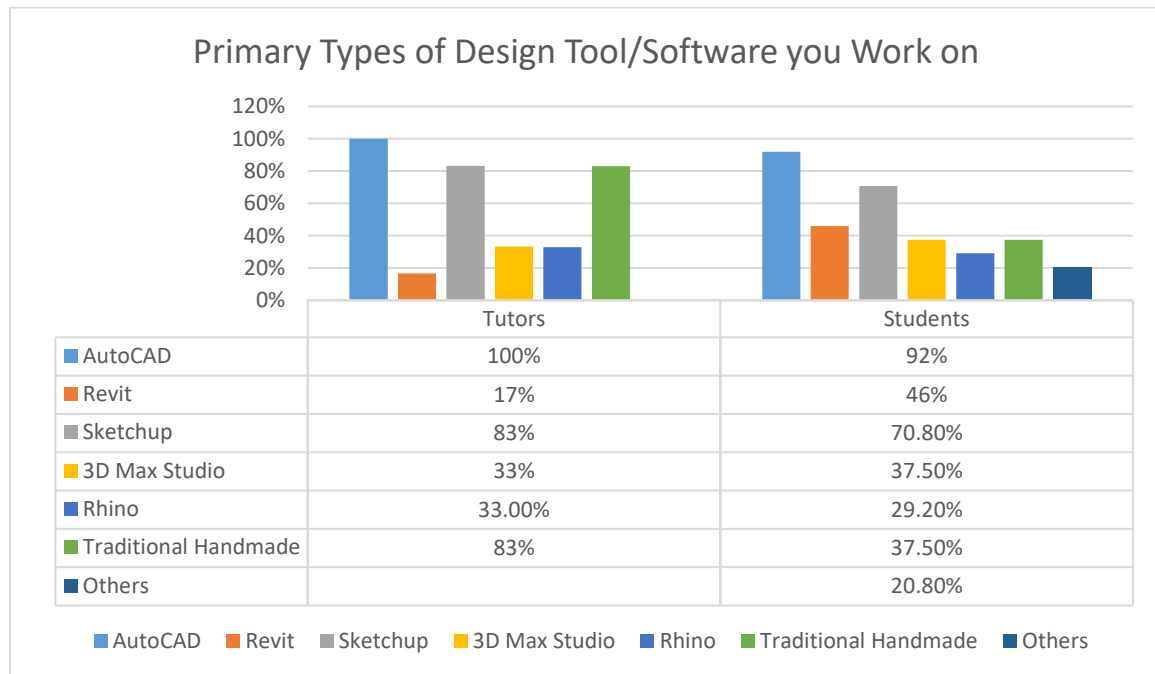
Figure 5.5.3.3 Respondents' years spent in architectural education.



Source: Compiled by the author (2022)

Analysis: Tutors have a broad range of experience, with most having over ten years in architectural education. This extensive experience can provide valuable insights and mentorship to students who are relatively new to the field, with the majority having only 1-4 years of experience. This mentorship can be particularly beneficial in helping students navigate the complexities of architectural design and the integration of new technologies like VR.

Figure 5.5.3.4 Primary Types of Design Tools/Software Used



Source: Compiled by the author (2022)

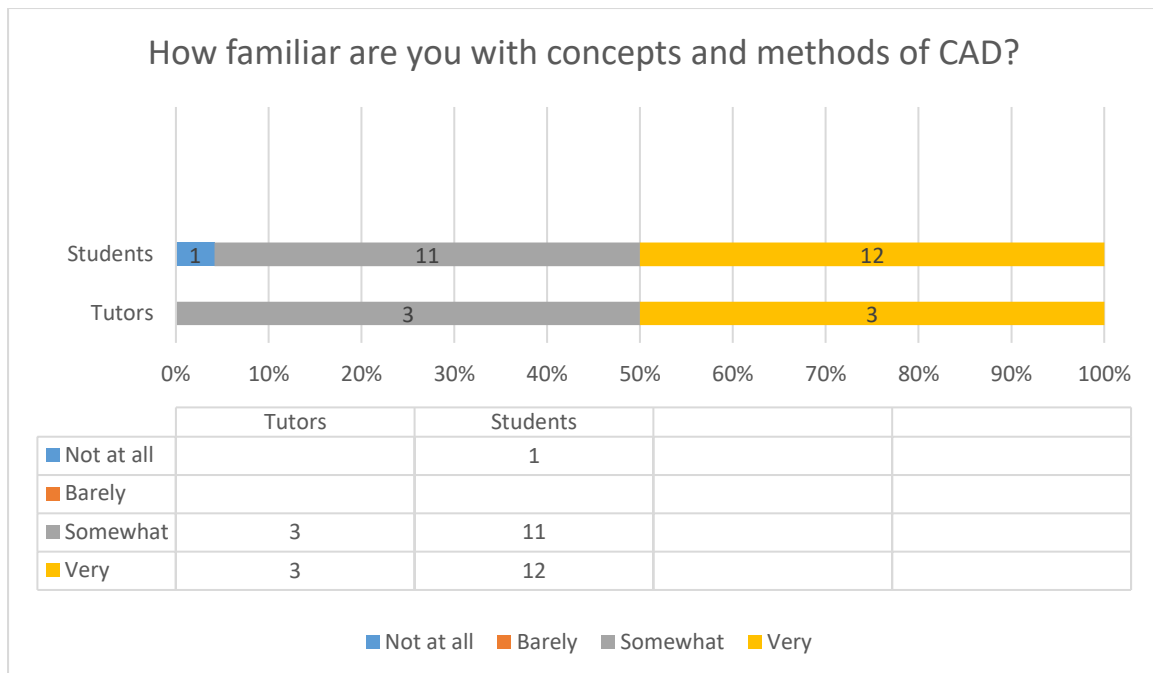
Analysis: Figure 5.5.3.4 shows that both tutors and students frequently use established design tools such as AutoCAD and SketchUp, while tutors often prefer traditional handmade methods for initial conceptual exploration. Although tools like SketchUp and physical model-making offer three-dimensional representations, they differ in how they support spatial perception and iteration. Screen-based CAAD tools can limit immersive spatial understanding because they rely on indirect manipulation through 2D interfaces (e.g., mouse and keyboard), whereas handmade models provide tangible interaction but lack the flexibility for rapid iteration or real-time feedback.

In contrast, VR offers an alternative mode of interaction by allowing students to experience their designs at a 1:1 scale, engage in immersive spatial exploration, and receive immediate feedback

on proportions, materiality, and user experience. Studies have shown that VR can enhance spatial cognition and iterative refinement in ways that traditional CAD tools and physical modeling cannot fully replicate (Portman, Natapov, & Fisher-Gewirtzman, 2015; Bergin et al., 2020).

However, while VR presents clear advantages, it is not intended to replace existing design tools but rather to complement them by providing an additional layer of experiential engagement. The study acknowledges that further research is needed to establish direct comparative evidence of how VR impacts the design iteration process relative to traditional tools.

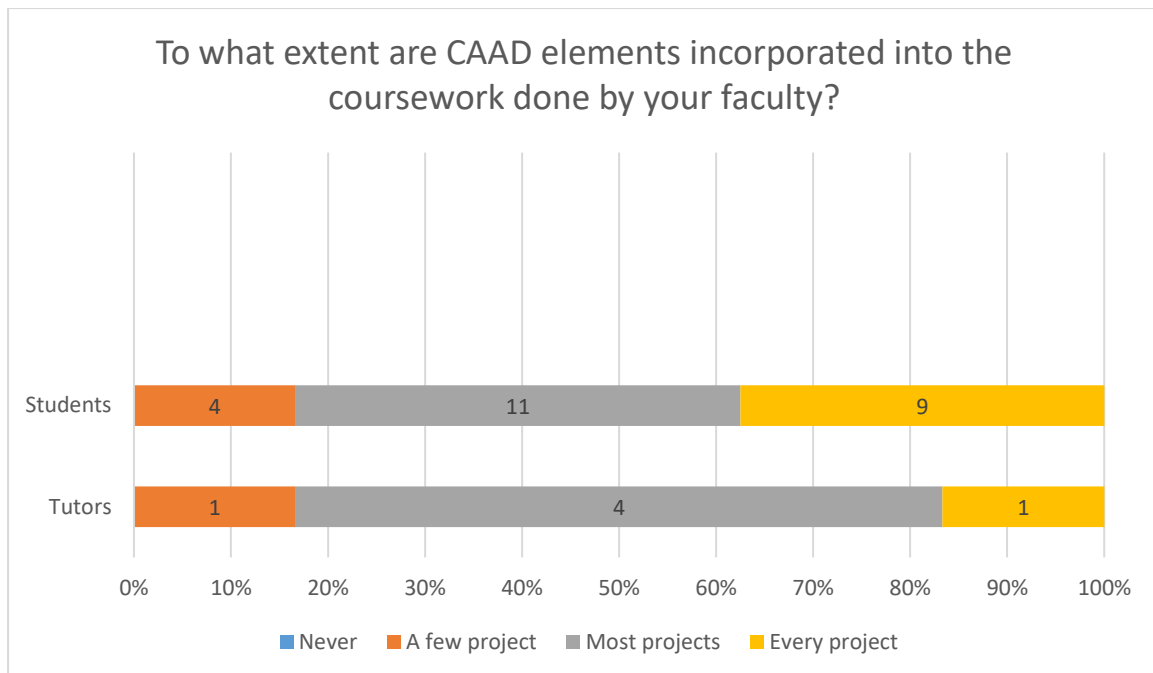
Figure 5.5.3.5 Familiarity with CAD Concepts and Methods



Source: Compiled by the author (2022)

Analysis: Figure 5.5.3.5 indicates that most participants are ‘somewhat’ to ‘very familiar’ with CAD and CAAD tools, reflecting a baseline proficiency in digital design methods. This familiarity is important because it can significantly ease the learning curve when transitioning to more advanced and immersive digital platforms like VR. Prior experience with CAD tools equips users with essential skills such as spatial visualization, digital manipulation, and design iteration—all of which are transferable to immersive environments (Ham & Schnabel, 2011). As a result, students with strong digital design foundations are better positioned to leverage VR effectively for conceptual development, spatial testing, and interactive exploration.

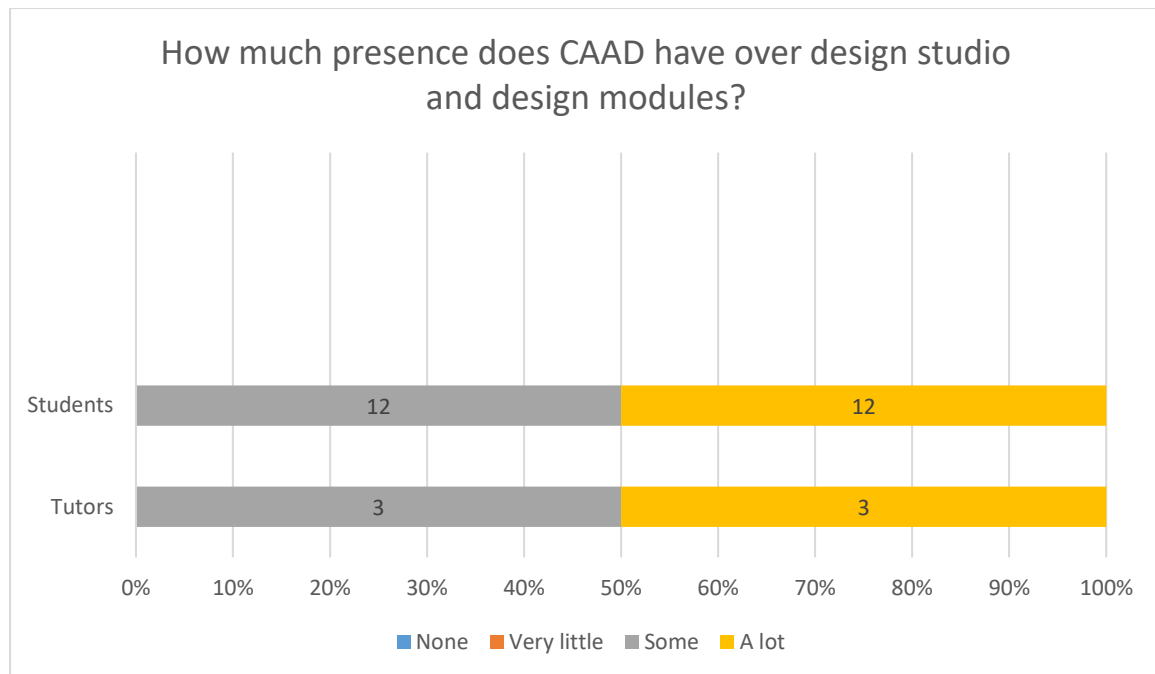
Figure 5.5.3.6 Incorporation of CAAD Elements into Coursework



Source: Compiled by the author (2022)

Analysis: Figure 5.5.3.6 shows that CAAD elements are frequently incorporated into coursework, with most participants indicating that these tools are used in ‘most’ or ‘every’ project. This consistent use suggests that digital design methods are well embedded in architectural curricula. It also reinforces the earlier observation of participant familiarity with CAD/CAAD (Figure 5.5.3.5), supporting the idea that students are progressively developing digital competencies. Such regular exposure creates a strong foundation for the introduction of VR, which builds upon similar principles of digital spatial manipulation and iterative design. Frequent engagement with CAAD is therefore a valuable precursor to immersive design workflows, helping to ease the pedagogical transition to VR-based approaches.

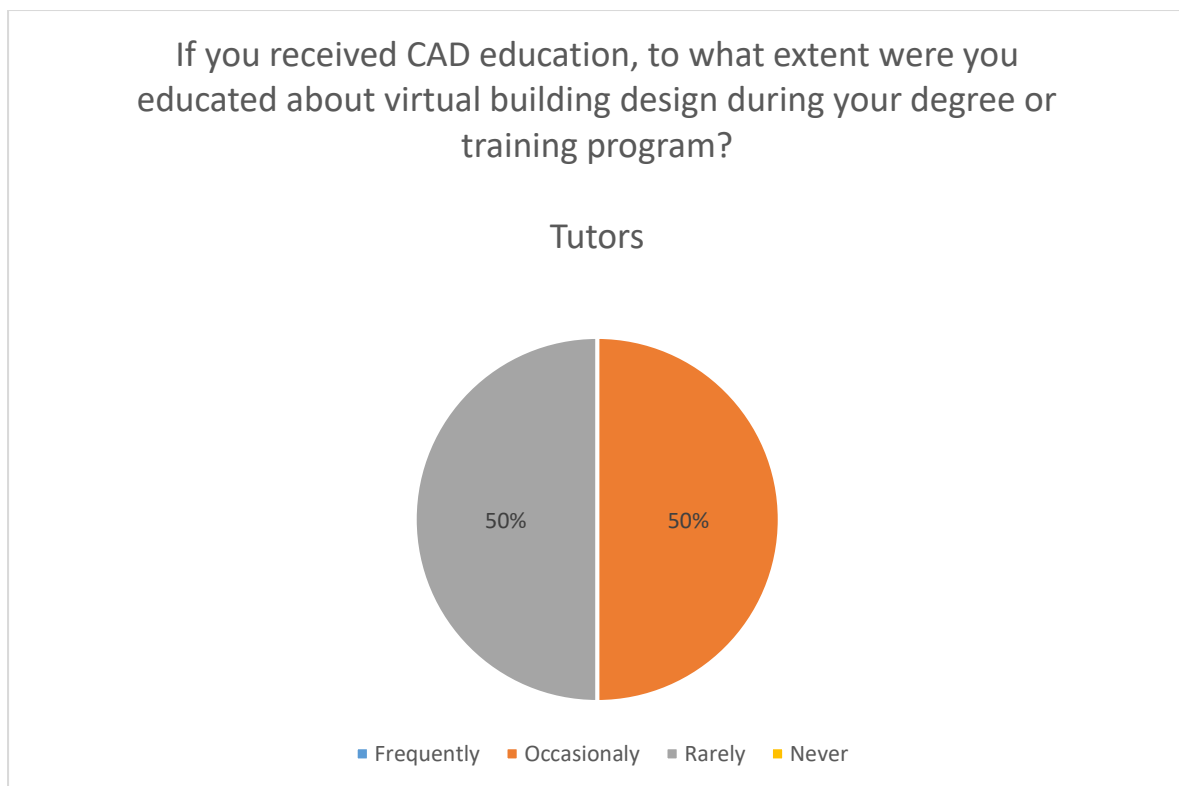
Figure 5.5.3.7 Presence of CAAD in Design Studios and Modules



Source: Compiled by the author (2022)

Analysis: The established presence of CAAD in design studios suggests a readiness to enhance these practices with VR technologies further. Regular incorporation of CAAD elements helps students develop a strong foundation in digital design, which can be built upon with VR to create more immersive and interactive design experiences.

Figure 5.5.3.8 Education on Virtual Building Design



Source: Compiled by the author (2022)

Analysis: This question highlights a significant gap in VR-related education. While most participants reported receiving CAD training, often focusing on 2D and 3D modeling for design visualization and documentation, the results show that few had any formal instruction in virtual building design or immersive technologies. This suggests that although students and tutors are digitally literate through CAD, they may not possess the competencies needed for VR integration.

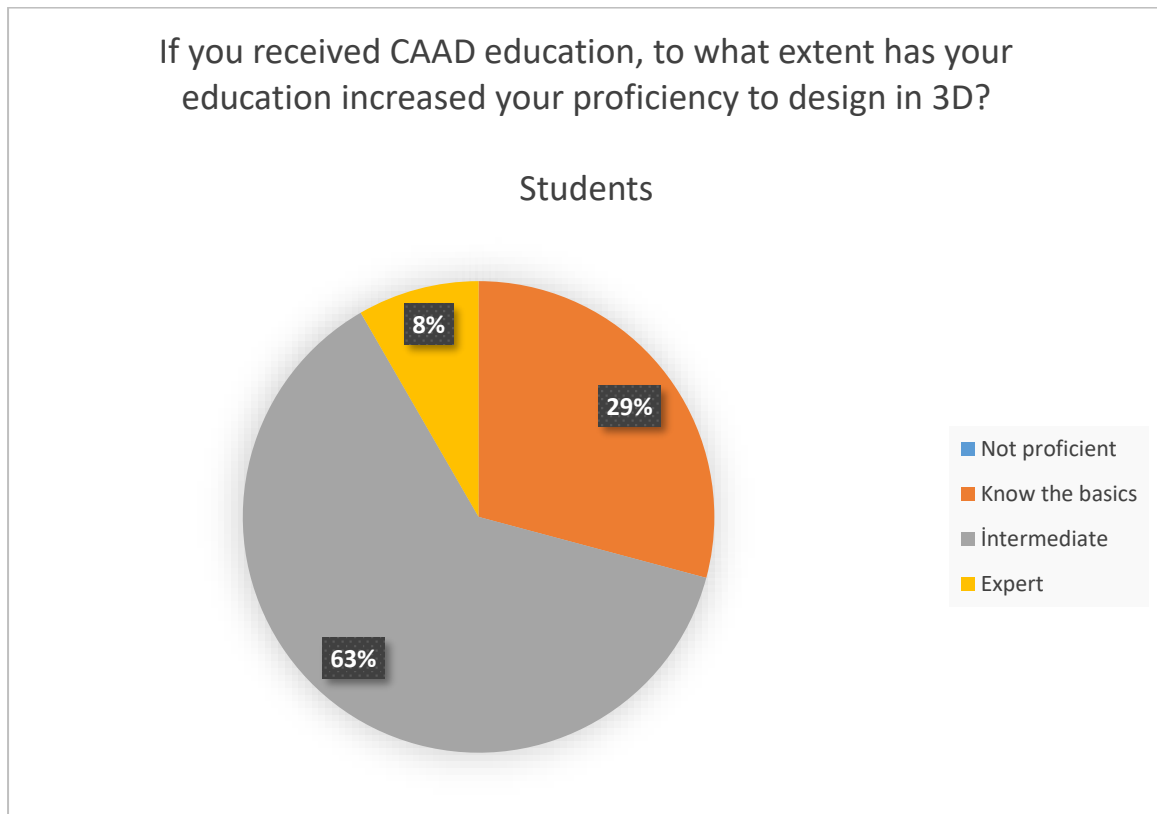
This insight directly complements the findings from Figure 5.5.3.5 (Familiarity with CAD Concepts and Methods) and Figure 5.5.3.6 (Incorporation of CAAD Elements into

Coursework), which showed high levels of digital familiarity and regular engagement with digital tools. However, as this figure demonstrates, such familiarity does not equate to preparedness for immersive environments, where the emphasis shifts to real-time spatial interaction, user embodiment, and immersive design evaluation.

Research confirms this distinction. Schnabel, Wang, and Kvan (2018), and Berg and Vance (2017), argue that effective VR use in architectural education demands a different skill set—particularly in spatial navigation, virtual object manipulation, and collaborative immersion.

To address this gap, architectural education should consider embedding standardized VR training alongside CAD instruction. This would ensure a more seamless transition from conventional digital tools to immersive technologies, enabling students and educators to confidently navigate virtual environments and meet evolving industry expectations.

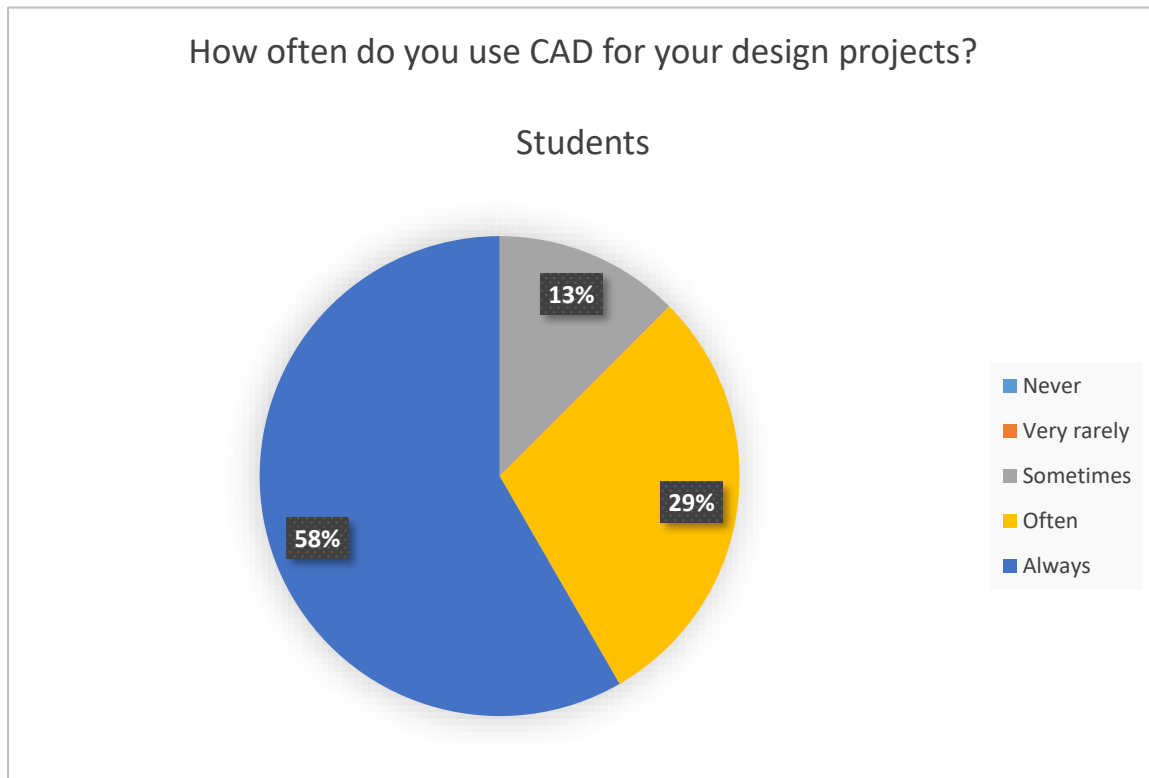
Figure 5.5.3.9 Proficiency in 3D Design Post-CAAD Education



Source: Compiled by the author, (2022)

Analysis: High proficiency in 3D design among students indicates that they are well-prepared to leverage VR for more advanced and immersive design projects. This level of proficiency can enable students to maximize the potential of VR technologies, enhancing their ability to create detailed and complex designs.

Figure 5.5.3.10 Frequency of CAD Use in Design Projects



Source: Compiled by the author, (2022)

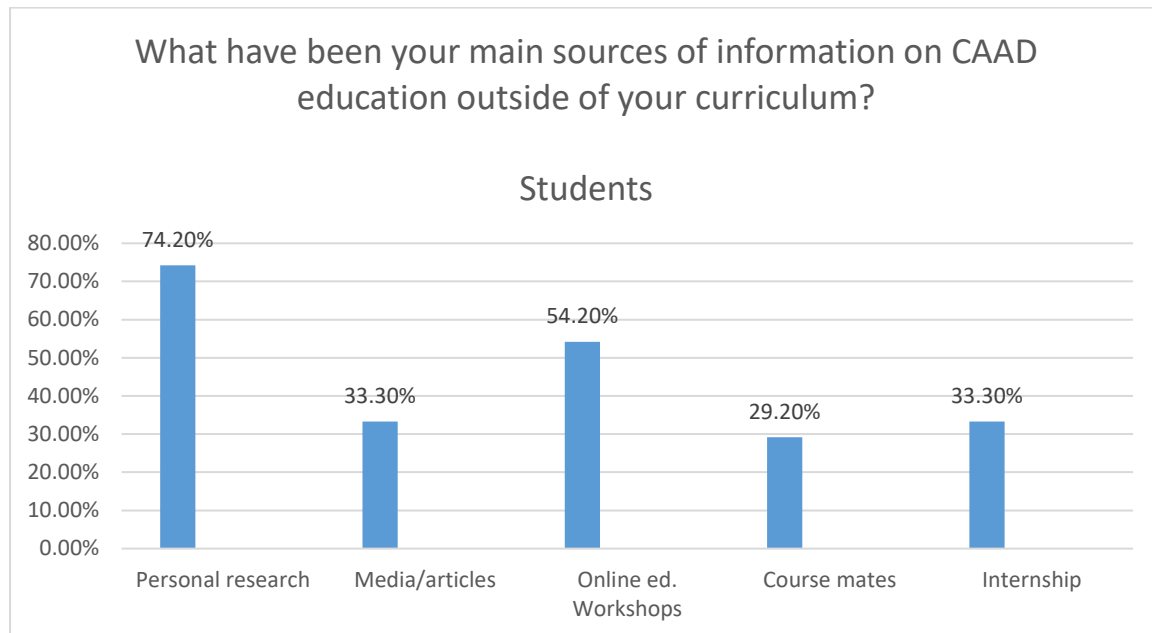
Analysis: The frequent use of CAD highlights students' familiarity with digital design environments, which may provide a foundational understanding of spatial modeling and digital workflows. However, this does not necessarily mean that the transition to VR is seamless, as the interaction methods between CAD and VR differ significantly.

While CAD is typically operated through a screen, keyboard, and mouse, allowing for indirect manipulation of 3D models, VR requires direct interaction with virtual

environments using headsets, motion controllers, and spatial navigation techniques. Studies have shown that while prior experience with CAD can offer transferable knowledge of 3D modeling, students still need specific training in VR navigation, spatial awareness, and real-time interaction techniques (Schnabel et al., 2018; Berg & Vance, 2017).

Thus, although CAD proficiency may reduce cognitive barriers to adopting VR, VR-specific training remains essential to ensure students develop the necessary interaction skills. Recognizing these distinctions can help architectural educators design a more structured transition process, ensuring that students can fully utilize VR as a design tool rather than just a visualization platform.

Figure 5.5.3.11 Main Sources of Information on CAAD Education (Students)



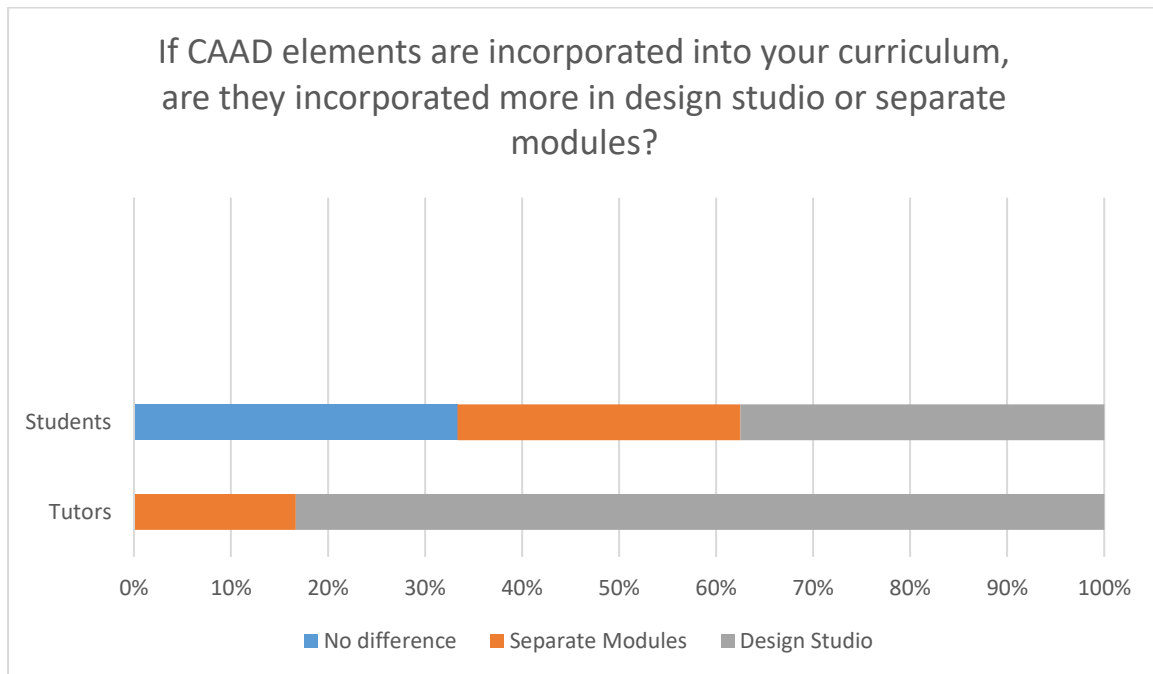
Source: Compiled by the author, (2021)

Analysis: The diversity of CAAD information sources reflects different learning approaches between students and tutors. Tutors tend to engage in personal research, collaboration with colleagues, and continuing education workshops, allowing for peer-to-peer learning and knowledge exchange. In contrast, students rely primarily on personal research and online education workshops, with less emphasis on learning through direct interaction with peers.

This distinction suggests that students' learning is often self-directed, relying on online resources and independent study, whereas tutors may benefit from a more structured professional development environment. While both groups engage in continuous learning, the mechanisms through which they stay updated differ. This has implications for integrating VR education, as tutors may require formalized training programs, while students may benefit more from on-demand, self-paced learning resources.

Recognizing these differences is important in designing VR integration strategies, ensuring that educators receive structured professional training, while students are provided with interactive, accessible resources that align with their independent learning habits.

Figure 5.5.3.12 Integration of CAAD in Curriculum



Source: Compiled by the author, (2022)

Analysis: The results reveal a notable discrepancy in perceptions between students and tutors regarding how CAAD is integrated into the architectural curriculum. Tutors overwhelmingly report that CAAD is incorporated into design studios (approximately 85%), while students display a more varied distribution, with a substantial number selecting “No difference” between design studios and separate modules.

This divergence may reflect different vantage points. Tutors—particularly those involved in studio teaching—may perceive CAAD as primarily situated within design studio

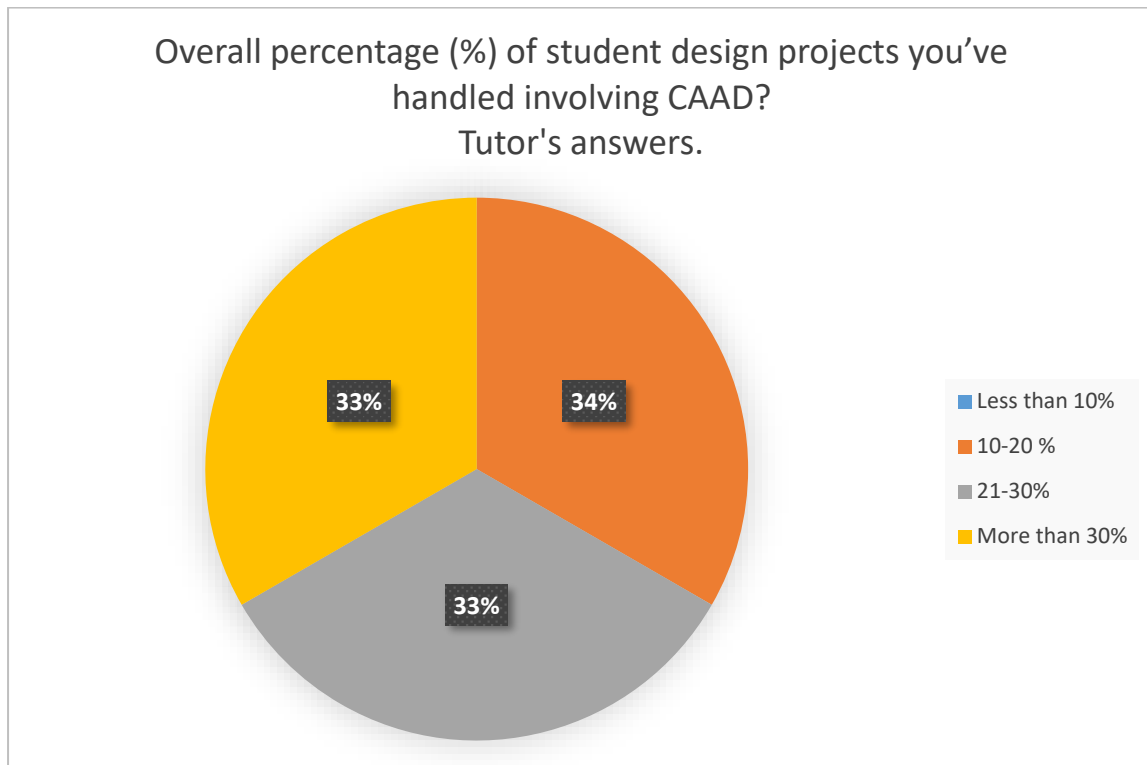
projects. However, many tutors, especially external practitioners or part-time lecturers, may not have full visibility over the breadth and interconnections of the entire curriculum. Conversely, students, who engage with all aspects of the program over time, may experience CAAD tools more fluidly across both studio and non-studio contexts, leading them to report a less compartmentalized view.

This perceptual mismatch carries important implications for the integration of VR into architectural education:

- If tutors primarily associate CAAD with studio-based learning, VR may be similarly implemented in design studio contexts, emphasizing iterative and collaborative design tasks.
- If students view CAAD as integrated across modules, VR implementation may need to extend beyond the studio to support a more holistic and flexible learning experience.

Recognizing these differing perspectives is crucial for shaping effective VR integration strategies that align tutor intentions with student realities—ensuring immersive technologies are embedded where they are most impactful.

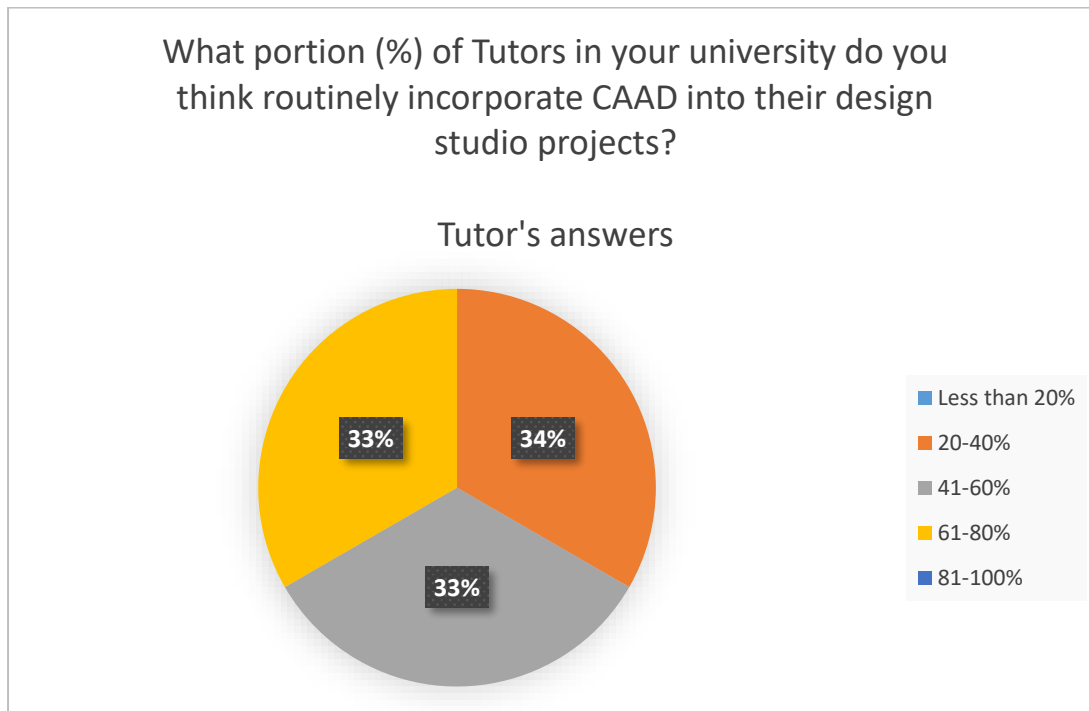
Figure 5.5.3.13 Percentage of Design Projects Involving CAAD



Source: Compiled by the author, (2022)

Analysis: The substantial integration of CAAD in design projects underscores the readiness for further incorporating VR technologies to enhance these projects. Regular involvement with CAAD tools in a significant portion of projects prepares both students and tutors to effectively use VR in their design processes.

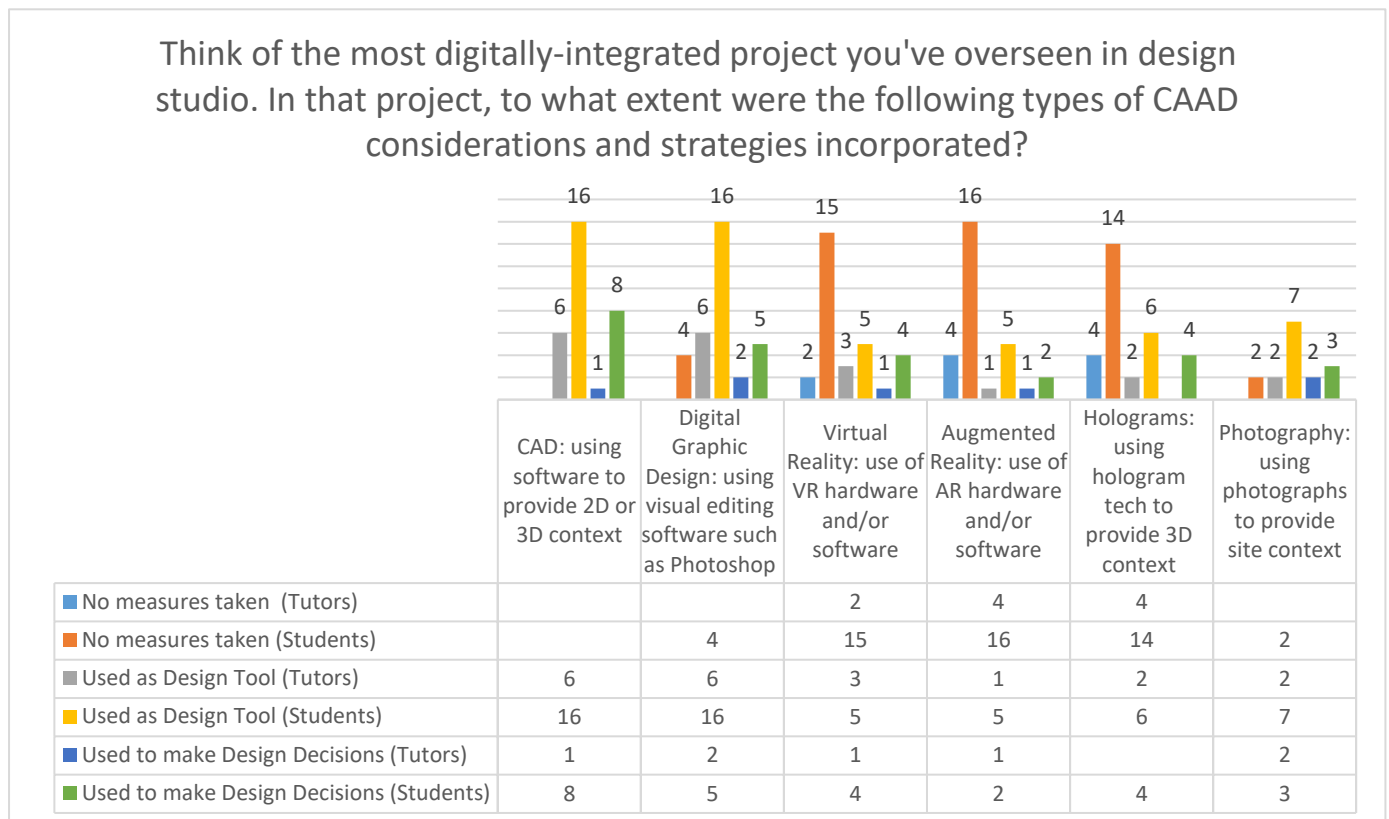
Figure 5.5.3.14 Routine Incorporation of CAAD by Tutors



Source: Compiled by the author, (2022)

Analysis: This variation suggests opportunities for increased adoption and standardization of CAAD and VR practices among tutors. Addressing the lower percentages can help in creating a more uniform integration of these technologies, enhancing the overall quality of architectural education.

Figure 5.5.3.15 Level of integration of various CAAD considerations and strategies



Source: Compiled by the author, (2022)

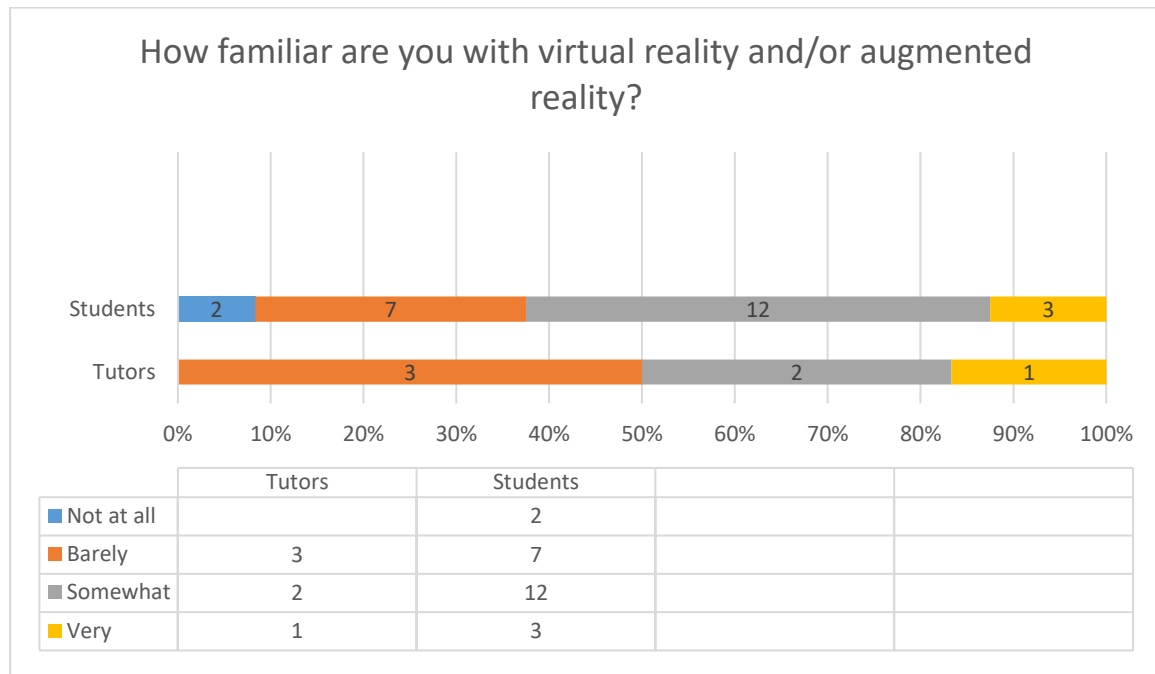
Analysis: This data suggests a hierarchy of digital adoption, where visual tools dominate and immersive tools are still transitioning from novelty to meaningful integration. Tutors and students alike demonstrate strong fluency with traditional CAAD platforms but show less engagement with immersive tools, especially in terms of decision-making influence.

This limited application of VR/AR and holograms may be due to:

- Resource access limitations
- Lack of staff or student training
- Uncertainty regarding the pedagogical value of immersive tools

As discussed in Chapter 2 (Section 2.4.3) and Chapter 3 (Section 3.5.1), CAAD tools historically emerged to serve representational purposes. This figure supports the view that current educational practices still lean toward representational utility, rather than process-driven or decision-making applications, particularly with emerging technologies.

Figure 5.5.3.16 Familiarity with VR/AR



Source: Compiled by the author, (2022)

Analysis: The results suggest that familiarity with VR/AR among students is polarized, with some reporting high familiarity (“Very”), while others indicate no familiarity at all (“Not at all”). In contrast, tutors exhibit a more moderate level of familiarity, with most responses falling within the “Barely” or “Somewhat” categories.

This variation indicates that while some students may be highly prepared to engage with VR/AR, others may require foundational training before they can fully integrate these technologies into their learning process. Therefore, rather than assuming universal readiness, it is essential to provide structured VR/AR training programs that accommodate both experienced and inexperienced users.

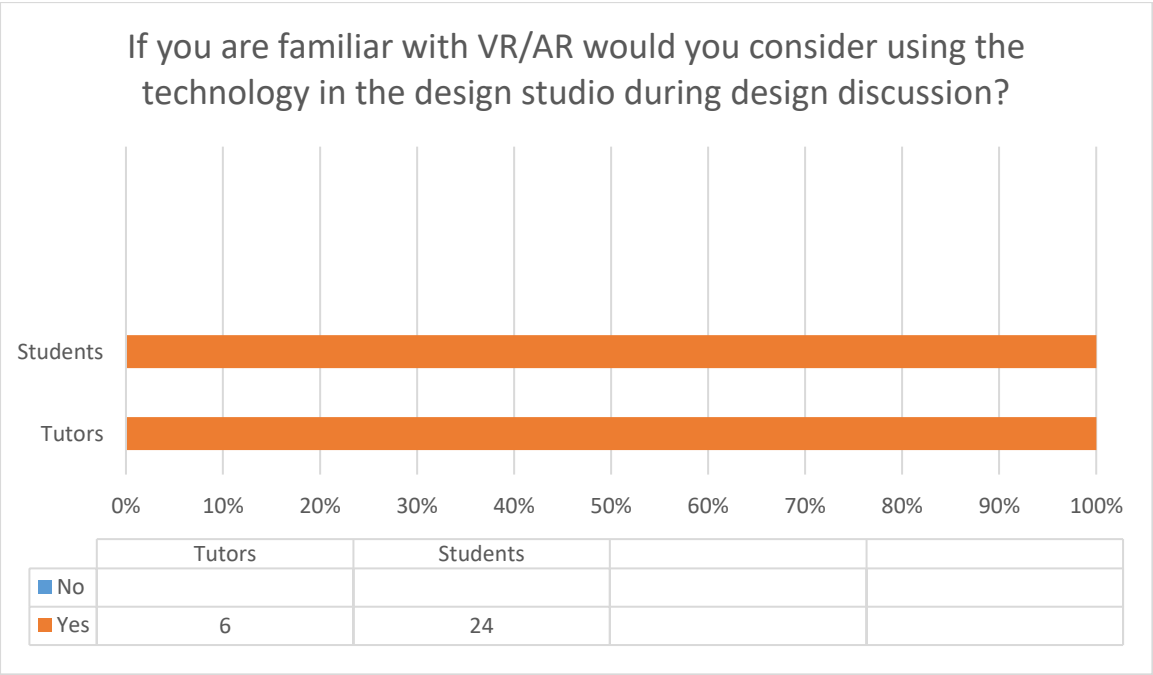
For effective integration into architectural education, educators should:

- Establish clear objectives and structured learning pathways for VR/AR adoption.

- Offer introductory sessions for students with no prior exposure to VR/AR.
- Provide advanced opportunities for students with existing knowledge to apply and refine their skills.

By ensuring that all students, regardless of familiarity level, receive appropriate training and guidance, educational institutions can create a more inclusive and effective learning environment for immersive technologies.

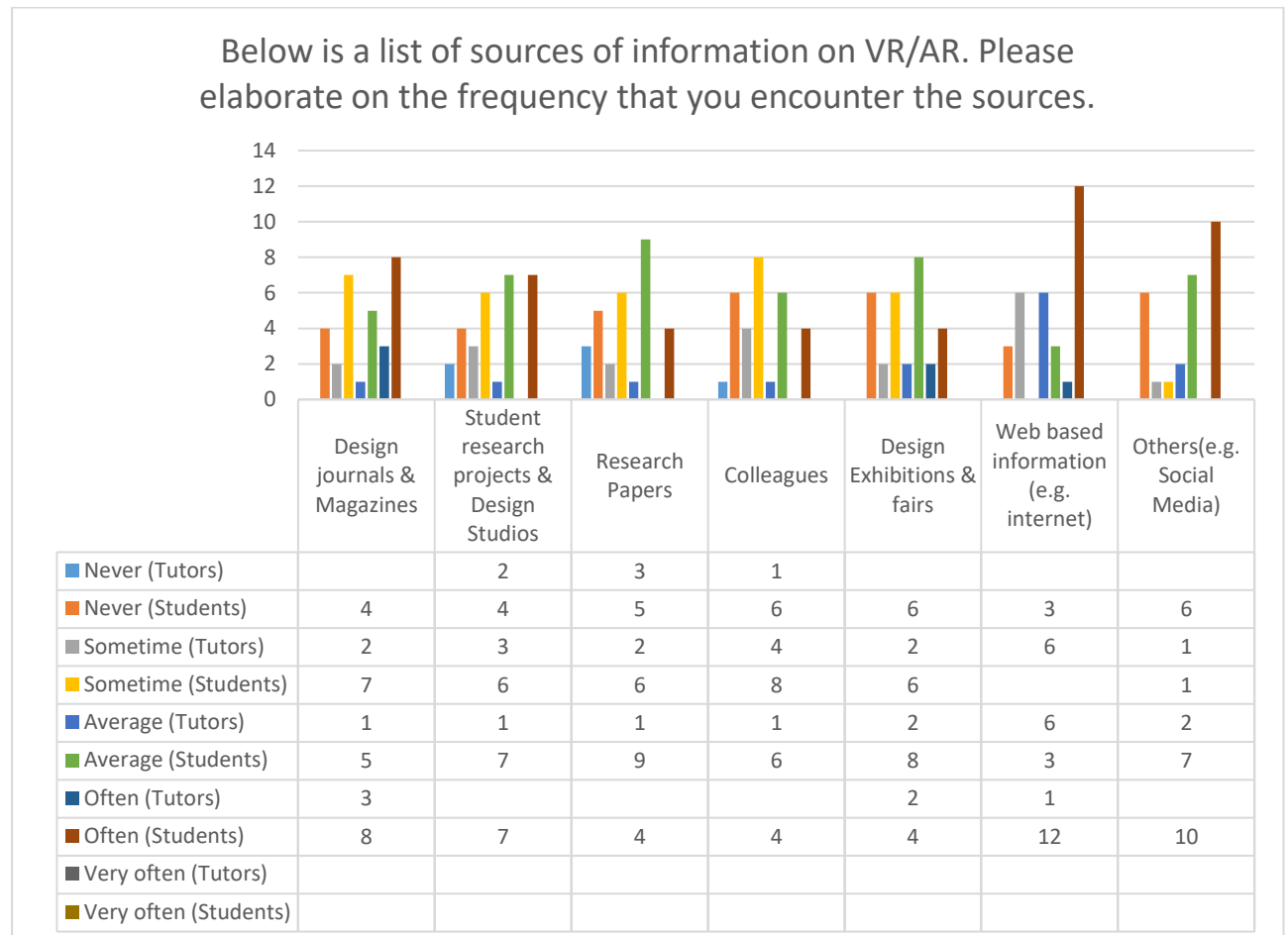
Figure 5.5.3.17 Willingness to Use VR/AR in Design Studios



Source: Compiled by the author, (2022)

Analysis: The strong interest in using VR/AR highlights the enthusiasm and openness to adopting new technologies in architectural education. This willingness provides a solid foundation for integrating VR/AR into the curriculum.

Figure 5.5.3.18 Sources of Information on VR/AR



Source: Compiled by the author, (2022)

Analysis: The results indicate contrasting patterns in how students and tutors access VR/AR information, which may influence how these technologies are integrated into education. Tutors rely more heavily on professional and academic sources, including student research projects, design studios, colleagues, and web-based information, with 20% or higher engagement in these areas compared to students. Students, on the other hand, tend to favor web-based sources and social media, relying less on peer information exchange through formal academic channels.

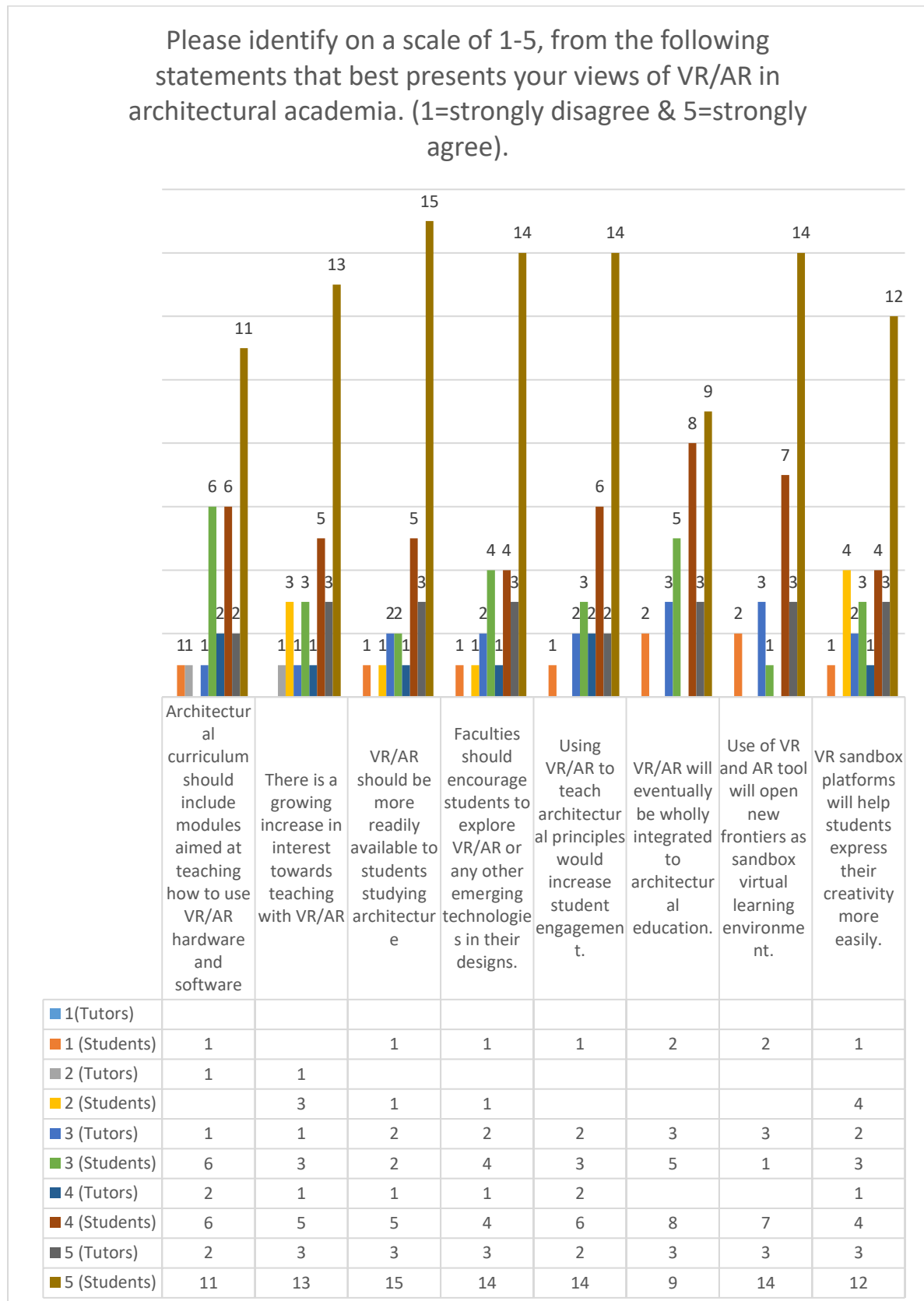
Tutors frequently consult design journals and magazines, whereas students engage more with online platforms and informal sources under the "Others" category, such as social media.

This divergence in information sources suggests that students may have fewer opportunities for structured, peer-driven learning about VR/AR, relying instead on self-directed exploration via online platforms. The limited exchange of resources among students may indicate a gap in collaborative learning that could be addressed by:

- Encouraging peer discussions and shared learning experiences within VR/AR-focused coursework.
- Providing structured academic resources that bridge the gap between self-directed online learning and formal academic sources.
- Ensuring that VR/AR-related educational content is accessible across multiple platforms, catering to both tutors' and students' preferred learning channels.

Recognizing these patterns can help educators tailor VR/AR training approaches, ensuring that both students and tutors have access to reliable, research-backed information while also leveraging the accessibility of online resources.

Figure 5.5.3.19 Views on VR/AR in Architectural Academia



Source: Compiled by the author, (2022)

Analysis: The results indicate strong overall agreement among both tutors and students regarding the benefits of VR/AR in architectural education. However, a notable perception gap exists between the two groups regarding how VR/AR will be integrated and its immediate impact on student engagement.

- Tutors are more optimistic about the long-term future of VR/AR, with higher agreement that VR/AR will eventually be fully integrated into architectural education.
- Students rate VR/AR higher than tutors when considering its ability to enhance engagement in learning architectural principles.

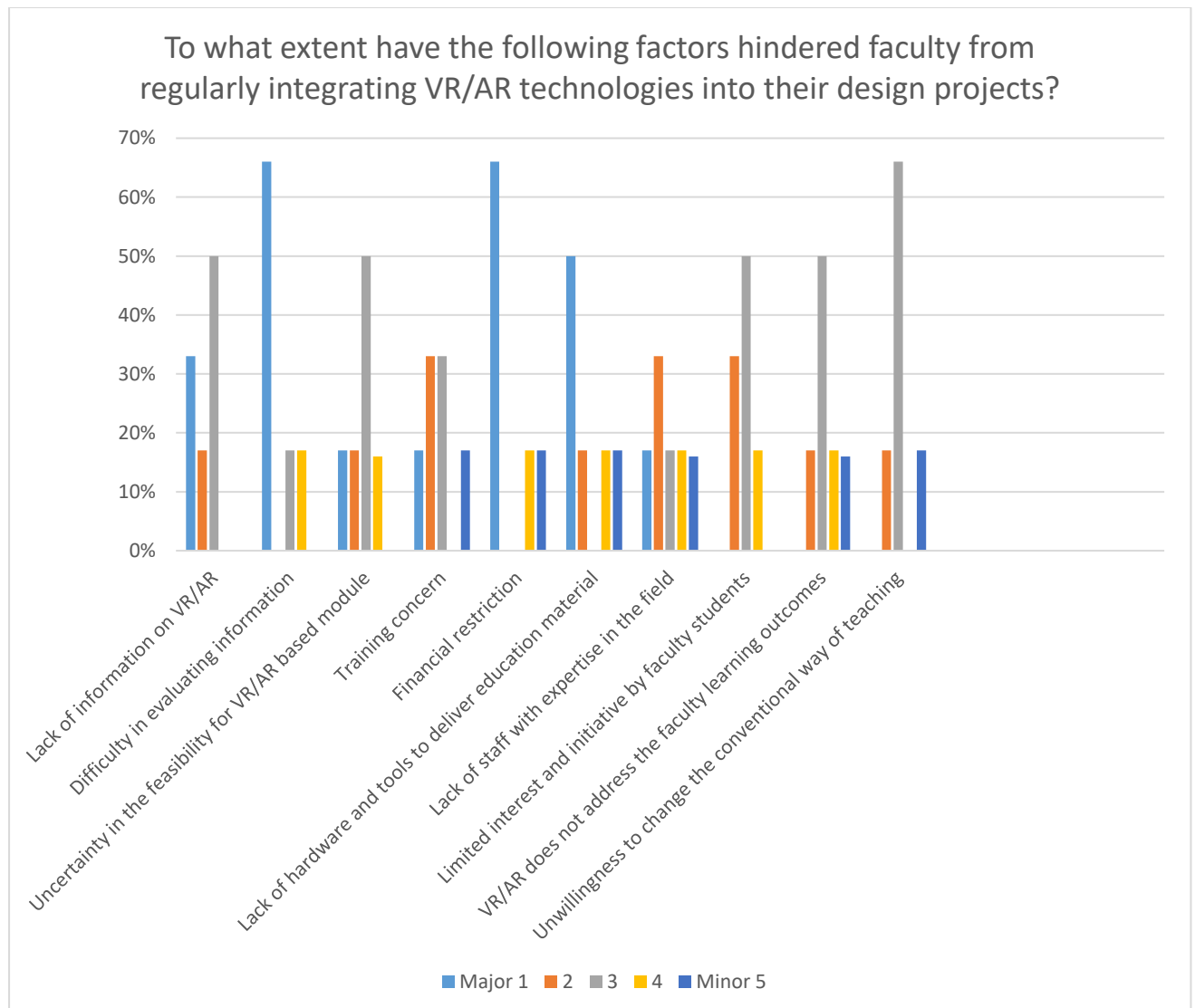
This perception reversal suggests that while tutors are forward-looking, anticipating full VR/AR adoption in the future, they may underestimate its immediate impact on engagement and learning outcomes. Meanwhile, students, who experience VR/AR firsthand in an educational setting, may be more attuned to its direct impact on their engagement but uncertain about its long-term institutional integration.

Implications for Architectural Education:

- Tutors may benefit from more exposure to student-centered feedback on VR/AR engagement, ensuring that teaching methodologies align with students' learning experiences.
- The gap in student expectations regarding full VR/AR integration suggests that students may not yet see institutional readiness for widespread adoption, highlighting the need for clearer curricular roadmaps that outline how VR/AR will be integrated over time.
- This contrast reinforces the importance of bridging long-term technological optimism with immediate pedagogical effectiveness, ensuring that VR/AR integration is both future-focused and responsive to current student needs.

Understanding these differing perspectives can help guide more effective VR/AR adoption strategies, ensuring that both educators' long-term visions and students' immediate learning experiences are aligned in architectural education.

Figure 5.5.3.20 Hindrances to Integrating VR/AR Technologies



Source: Compiled by the author, (2022)

Analysis: The findings indicate several key barriers to integrating VR/AR in architectural education, including lack of information, financial restrictions, limited hardware, and expertise. Additionally, a significant challenge that must not be overlooked is difficulty in evaluating information—the ability to critically assess VR/AR content, its relevance, and its pedagogical effectiveness. While investment in training, resources, and infrastructure is crucial, addressing

these barriers must also involve improving information literacy among students and educators.

The difficulty in evaluating information suggests that:

- Students and tutors may struggle to distinguish between credible and unreliable sources when learning about VR/AR.
- A lack of established best practices and guidelines for integrating VR/AR into design education may contribute to uncertainty.
- The rapid evolution of VR/AR technologies means that training programs must not only provide technical skills but also teach participants how to critically evaluate emerging tools and resources.

This expanded understanding of hindrances ensures a more comprehensive approach to integrating VR/AR, emphasizing that training efforts should include not only technical competency but also the ability to critically engage with new technologies and information sources. By considering both quantitative and qualitative barriers, this analysis provides a clearer foundation for assessing the impact of the VR workshops on participants' design processes and learning outcomes.

CONCLUSION?

5.6 VR Workshop and Observations

The workshop itself consisted of four design sessions, each lasting approximately 2 hours. During these sessions, students were tasked with developing architectural concepts using Gravity Sketch, focusing on creative exploration, spatial design, and iterative refinement. Tutors were present during the sessions to offer feedback and guidance, mirroring the traditional studio critique format but within the VR environment.

Throughout the workshop, the researcher observed how students interacted with the VR tools, how they responded to tutor feedback, and how effectively they communicated their design ideas within the virtual environment. The observations focused on identifying moments where the immersive nature of VR either enhanced or hindered the design process, particularly in relation to creativity, communication, and confidence. Observational data has been used in previous studies to complement quantitative findings and provide deeper insights into participant behavior (Birt et al., 2018).

5.6.1 Post-Experiment Interviews

Following the completion of the VR workshop, participants took part in semi-structured interviews to provide qualitative data on their experiences. The interviews were designed to explore participants' reflections on the creative process, their communication with tutors and peers, and their overall confidence in presenting their designs.

Sample interview questions included:

- "How did using VR change the way you approached the design process?"
- "Did you find it easier or more difficult to communicate your design ideas in VR compared to traditional methods?"
- "How did the immersive nature of VR affect your confidence in presenting your designs?"

The interviews were transcribed and analyzed using thematic analysis, identifying recurring themes related to the core research questions. This qualitative data provided rich, detailed insights into the participants' experiences, complementing the quantitative findings from the pre- and post-experiment questionnaires.

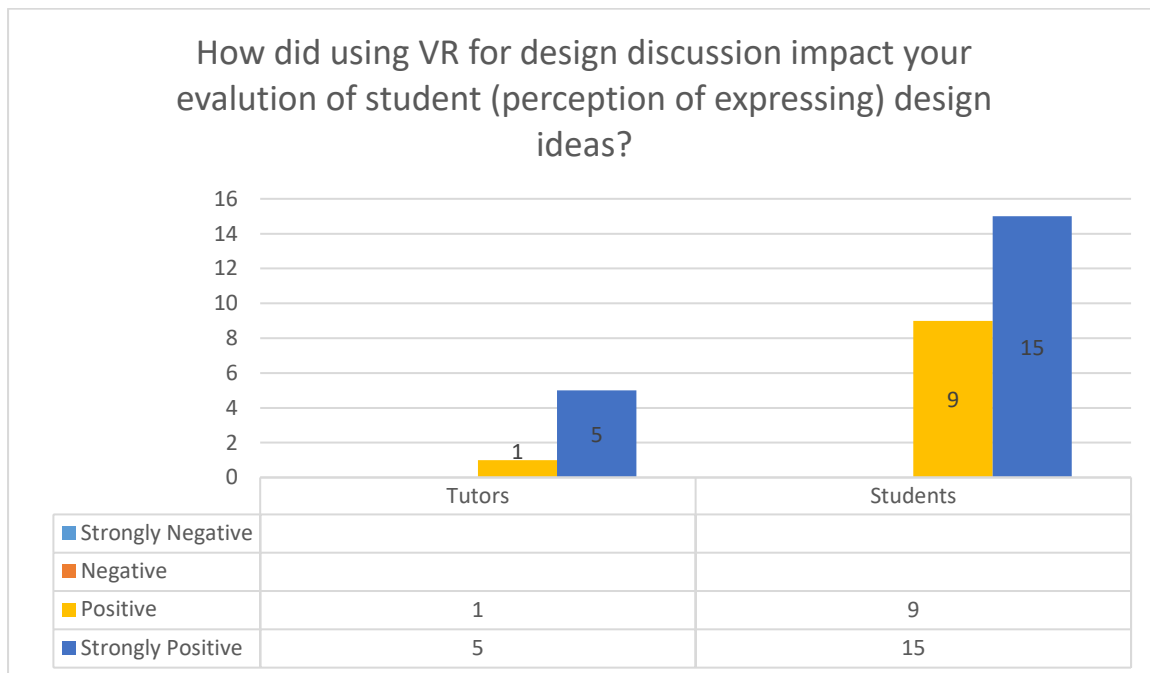
5.6.2 Post-Experiment Questionnaires

To quantify the changes in participants' creativity, communication skills, and confidence, a post-experiment questionnaire was administered. Like the pre-experiment questionnaire, this used Likert-scale questions to measure participants' self-assessment of these factors. The post-experiment data was compared to the baseline data using descriptive statistics, providing a clear picture of how participants' perceptions and abilities evolved over the course of the workshop.

By employing both quantitative and qualitative data collection methods, this study aimed to capture a comprehensive understanding of how VR impacted architectural education. The combination of surveys, interviews, and observations provided a well-rounded analysis of the key research questions, ensuring that both objective measurements and subjective experiences were considered.

5.7 Post experiment Results Analysis for VR (Virtual Reality) Workshop

Figure 5.7.1 Impact of VR on Student Confidence



Source: Compiled by the author, (2022)

Description: This graph illustrates the perceptions of both tutors and students on how the use of VR impacted the expression of design ideas during the workshops.

Analysis:

Students: A significant majority of students rated the impact of VR as Strongly Positive, indicating that it significantly enhanced their ability to express design ideas. This finding is crucial as it suggests that VR can transform traditional design discussions by providing a more immersive and interactive platform. One likely factor behind this perception is VR's capacity to visualize designs in a 3D space, which may enhance communication by:

- Allowing students to experience their designs at full scale, reinforcing spatial clarity.

- Enabling more precise feedback, as tutors and peers can engage with the design from within the virtual environment rather than through static 2D representations.

However, to confirm that VR is the primary factor improving communication, a parallel study could compare:

- Group A: Using VR tools (e.g., Gravity Sketch) with a headset.
- Group B: Using the same software on a standard screen without immersion.

By assessing communication effectiveness, design clarity, and feedback precision in both groups, we could isolate the unique advantages of VR over traditional screen-based visualization. Future research should explore this comparative approach to validate whether the immersive aspect of VR alone is responsible for the observed improvements.

Tutors: Tutors also reported positive impacts, indicating that they found VR beneficial in evaluating student design ideas. The immersive nature of VR enables tutors to engage with student designs in a more detailed and interactive manner, likely leading to more effective and insightful feedback. This suggests that VR can enhance the overall quality of design education by facilitating deeper understanding and more constructive critique.

Statistical Analysis:

A Mann–Whitney U test comparing post-experiment confidence between students and tutors produced a result of $U = 38$ ($p = 0.067$), indicating a trend toward higher confidence among tutors, though not statistically significant at the 0.05 level.

However, within-group Wilcoxon signed-rank tests showed statistically significant increases in self-reported confidence for both groups:

- Students (Pre vs Post): Statistic = 79, $p = 0.024$
- Tutors (Pre vs Post): Statistic = 0, $p = 0.031$

Mean post-confidence scores reflect these improvements:

- Students: 4.069
- Tutors: 4.317

While tutors showed slightly higher post-confidence scores on average, the between-group difference did not reach statistical significance. Still, the significant gains within each group highlight VR's effectiveness in improving participants' self-confidence in expressing and engaging with design ideas.

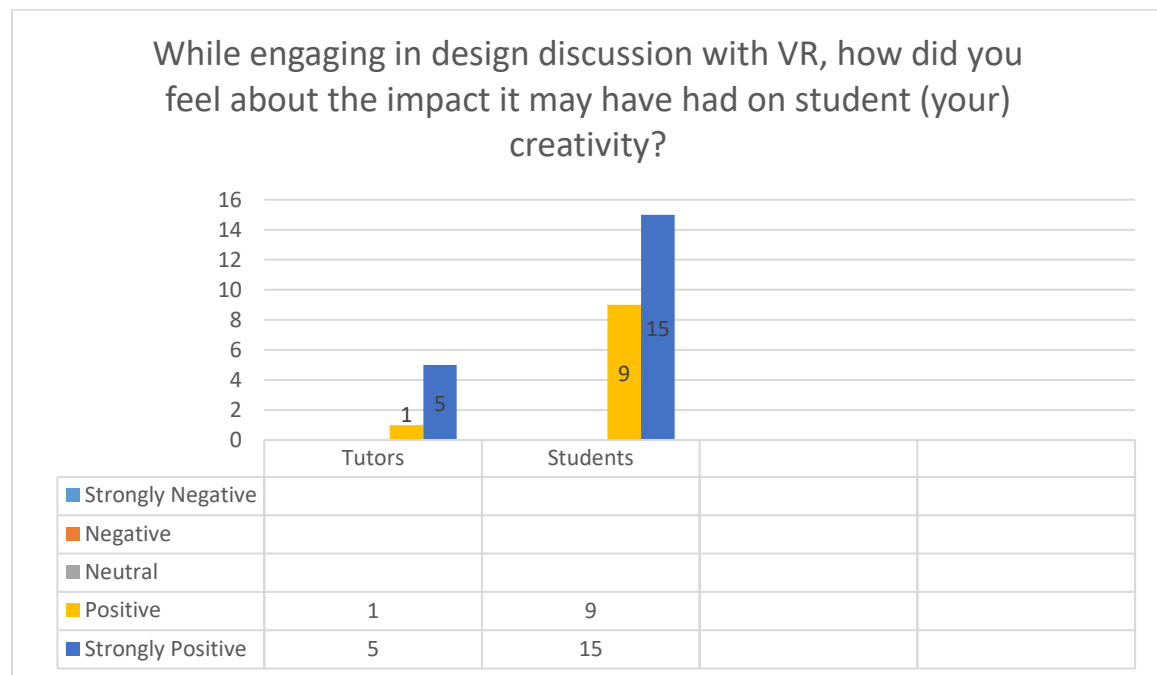
Further Considerations and Future Work:

To better isolate the role of immersion in these outcomes, future studies should compare:

- Group A: Students using immersive VR tools (e.g., Gravity Sketch via headset)
- Group B: Students using the same tools on non-immersive 2D screens

Such a comparison would help identify whether the improvements stem from the immersive experience itself or from the tool's interface, regardless of medium. Supplementing this with qualitative data (e.g., observations or think-aloud protocols) would offer additional depth into how immersive environments shape communication and confidence in design education.

Figure 5.7.2 Impact of VR on student creativity



Source: Compiled by the author, (2022)

Description: This graph shows the perceived impact of VR on student creativity during design discussions, as reported by both students and tutors.

Analysis:

Students: The majority of students felt VR had a Strongly Positive impact on their creativity. This can be attributed to the immersive and interactive nature of VR, which allows for a more explorative approach to design. The ability to manipulate and interact with design elements in a 3D space likely encouraged students to think more creatively and experiment with different ideas.

Tutors: Tutors similarly perceived a positive impact, indicating that VR facilitated creative expression during design discussions. This suggests that VR not only benefits students but also enhances the teaching experience by providing tutors with a more effective tool for fostering creativity.

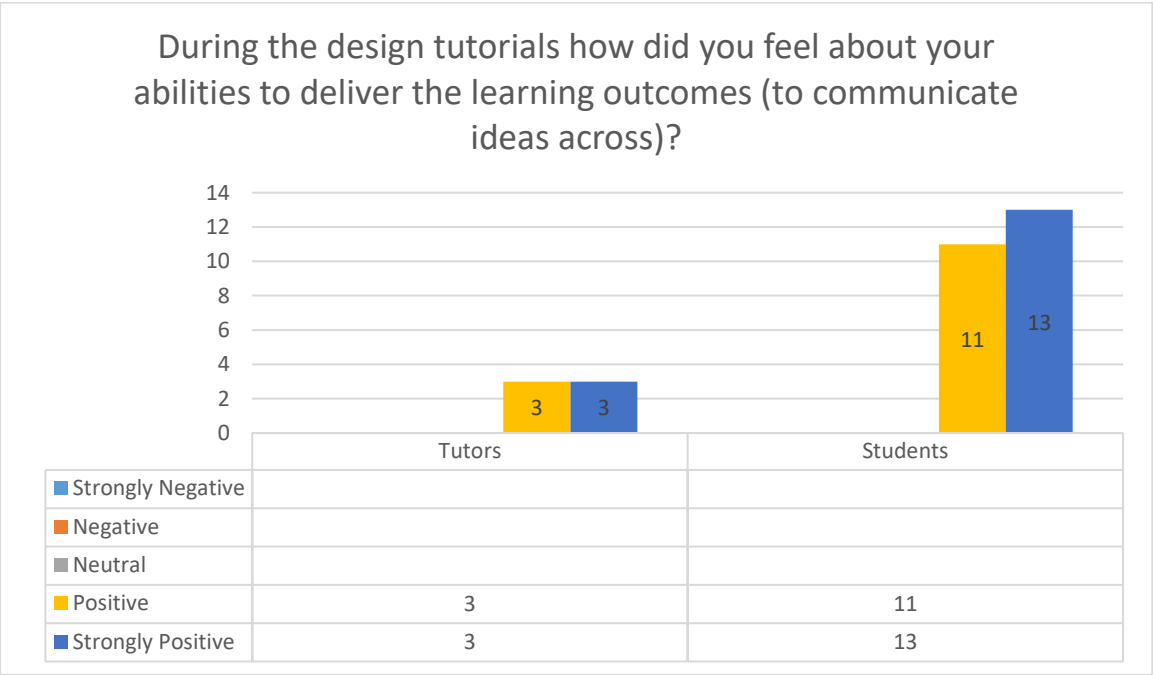
Statistical Analysis:

Statistical testing confirmed that VR engagement had a statistically significant impact on perceived creativity for both students and tutors. A Mann–Whitney U test comparing post-experiment creativity scores revealed a significant difference between the two groups ($U = 39$, $p = 0.035$), with tutors reporting higher creativity than students. All tutors rated their creativity at the maximum score (5.0), producing a uniform distribution that may reflect both a ceiling effect and the influence of professional expertise.

Wilcoxon signed-rank tests demonstrated significant within-group increases in creativity for both cohorts. Among students, scores rose from a pre-workshop mean of 3.87 to 4.52 post-workshop ($p = 0.002$). Tutors showed an increase from 3.839 to a perfect 5.0 ($p = 0.031$). While both groups reported gains, the tutors' perfect post-score distribution (standard deviation = 0.0) suggests that their existing proficiency allowed them to immediately and fully harness the creative potential of VR. In contrast, student scores showed minor variability ($SD = 0.51$), indicating that factors such as prior VR familiarity or design confidence may have influenced the extent of their creative engagement.

These results reinforce the qualitative perceptions captured in Figure 5.7.2, triangulating with the overwhelmingly Strongly Positive responses from both groups. However, the statistical contrast between students and tutors highlights the role of experience and digital fluency in maximising the creative benefits of immersive tools. This finding aligns with discussions in Chapter 3 regarding the relationship between play, exploration, and creativity in immersive environments (Malinin, 2016; Resnick, 2007), as well as the importance of scaffolding and training in equitable technology integration.

Figure 5.7.3 VR abilities to deliver the learning outcomes



Source: Compiled by the author, (2022)

Description: This graph reflects the confidence levels of students and tutors in their ability to communicate ideas and achieve learning outcomes using VR during design tutorials.

Analysis:

Students: Most students rated their ability to communicate ideas as Strongly Positive, suggesting that VR enhanced their confidence in delivering learning outcomes. This indicates that VR can improve students' self-efficacy in design communication, a critical skill in architectural education and practice.

Tutors: Tutor responses, however, were more varied, with some expressing confidence and others reporting challenges. This analysis is primarily based on questionnaire responses, where tutors and students showed similar response ratios. However, in follow-up interviews, some tutors highlighted difficulties in adapting to VR for communication, particularly in terms of:

- Interpreting student work in an immersive environment.
- Providing precise verbal feedback while navigating VR tools.
- Adjusting to new modes of interaction that differ from traditional critiques.

This suggests that the difference in interpretation may not be fully reflected in the questionnaire data alone. While both students and tutors reported positive experiences numerically, qualitative insights from interviews indicate that some tutors found the transition to VR more challenging than students did.

This highlights the need for comprehensive training sessions, ensuring that both students and tutors develop fluency with VR tools. By addressing these challenges, VR can become a more effective medium for enhancing communication in architectural education.

Statistical Analysis:

The impact of VR on participants' confidence in delivering learning outcomes—particularly their ability to communicate ideas effectively during tutorials—was assessed using both between-group and within-group comparisons.

A Mann–Whitney U test revealed a statistically significant difference between students and tutors in their post-workshop confidence levels ($U = 20.5, p = 0.007$). Interestingly, and somewhat counterintuitively, tutors reported higher post-VR confidence than students, despite qualitative data suggesting that some tutors encountered difficulties adapting to immersive environments. This divergence highlights the value of triangulating quantitative findings with interview insights, particularly when evaluating new pedagogical tools.

Both groups demonstrated statistically significant within-group improvements based on Wilcoxon signed-rank tests:

- Students: *Statistic* = 36.0, $p < 0.001$, indicating a highly significant increase in confidence regarding learning outcomes post-VR.

- Tutors: *Statistic* = 0.0, *p* = 0.031, also showing significant improvement, albeit from a slightly higher baseline.

Mean score shifts support these findings:

- Students: Mean confidence rose from 3.392 to 4.095
- Tutors: Mean increased from 3.419 to 4.729

Although students reported high levels of improvement, tutors experienced a larger overall gain ($\Delta \approx +1.31$ compared to students' $\Delta \approx +0.70$). This may be due to their ability to rapidly integrate VR functionality into pedagogical tasks, such as guiding spatial critiques, modelling feedback, or annotating ideas in real-time.

Distribution data provides further insight:

- Students' post-confidence ranged from 3.53 to 5.00 (SD $\approx$ 0.42), suggesting some variability, likely due to differences in prior VR experience or confidence in public communication.
- Tutors exhibited a tighter and higher range (Min $\approx$ 4.20, Max = 5.00, SD $\approx$ 0.29), reflecting more consistent perceptions of effectiveness.

However, qualitative data from tutor interviews complicates this statistical picture. While numerical responses were positive, several tutors described initial challenges, including:

- Difficulty interpreting complex student work within immersive environments.
- Challenges navigating VR while maintaining verbal fluency during feedback.
- A learning curve in adapting to new interaction paradigms, which differed from traditional studio critique.

These observations suggest that while statistical results confirm positive impact, they may also mask transitional struggles. Therefore, future implementation should include dedicated VR training, not only for students but also for tutors—helping both groups build fluency and reduce cognitive load during teaching and learning.

The findings align with studies discussed in Chapter 3, where digital confidence and spatial literacy are identified as critical mediators in the successful use of immersive technology (e.g., Milovanovic et al., 2017; Oxman, 2006). They also reflect broader themes in architectural education that emphasize the role of technological literacy in shaping both delivery and reception of spatial knowledge.

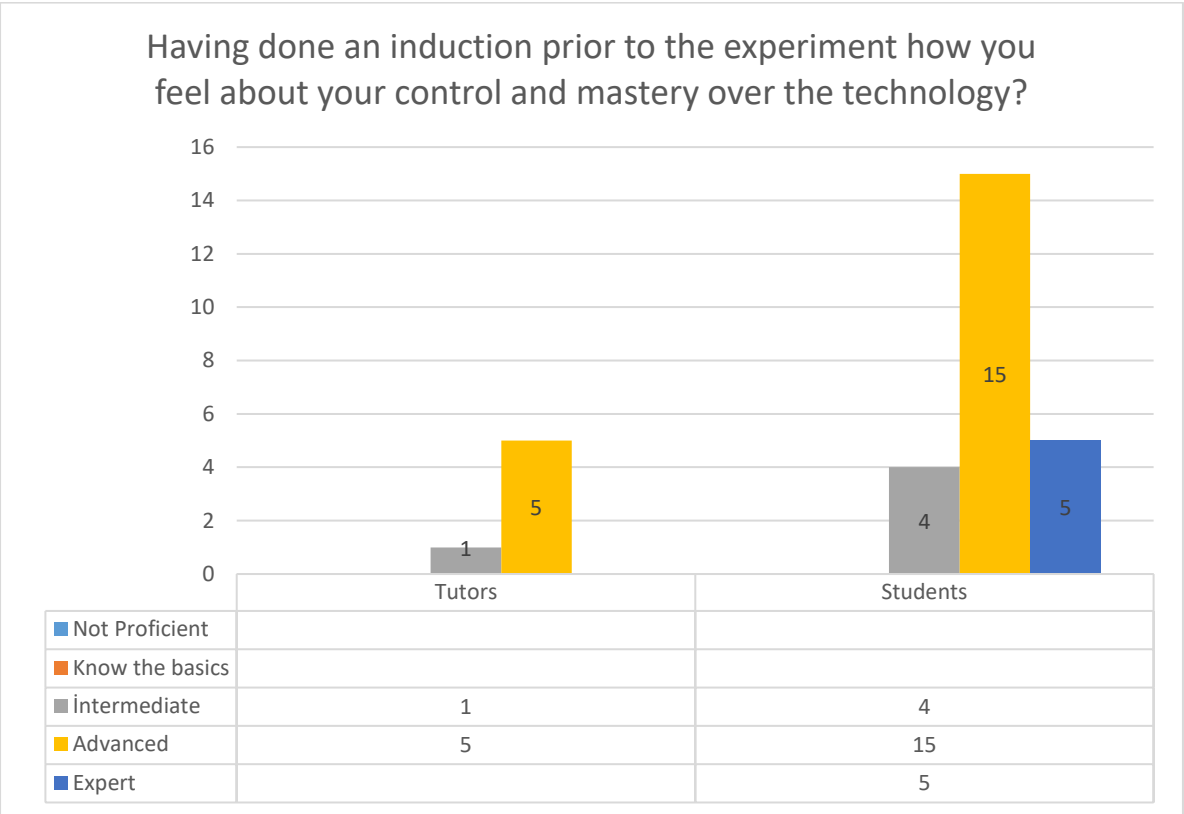


Image 5.7.1 Student and Tutor having design discussion in the University of Nicosia (source: author 2021)



Image 5.7.2 Students and Tutor design discussion in the University of Kyrenia (source: author 2021)

Figure 5.7.4 Control and mastery over the VR technology



Source: Compiled by the author, (2022)

Description: This graph assesses the proficiency of students and tutors in using VR technology after the induction sessions.

Analysis:

Students: The majority reported high proficiency, indicating that the induction sessions were effective in preparing users to utilize the VR tools competently. This suggests that with adequate training, students can quickly become proficient in using VR, which is essential for integrating this technology into the curriculum.

Tutors: Tutors generally felt confident, but some indicated a need for ongoing support and practice. This underscores the importance of continuous professional development to ensure tutors remain adept at using new technologies in their teaching practices.

Statistical Analysis:

The effectiveness of the induction sessions in building participants' control and confidence over the VR technology was evaluated using both between-group and within-group comparisons.

A Mann–Whitney U test indicated no statistically significant difference between tutors and students in their post-induction VR mastery scores ($U = 46, p = 0.158$). This finding suggests that both groups reached comparable levels of technical proficiency by the end of the training. Despite differences in prior exposure, the structured induction proved effective in elevating both cohorts to similar levels of competence.

However, within-group Wilcoxon signed-rank tests revealed significant improvements for both groups:

- Students: *Statistic* = 8, $p < 0.001$ — a highly significant increase in perceived mastery.
- Tutors: *Statistic* = 0, $p = 0.031$ — also significant, with a strong upward shift from their baseline.

Mean score improvements provide further clarity:

- Students: Mean increased from 2.649 (between intermediate and advanced) to 4.097 (advanced range), a gain of approximately +1.448.
- Tutors: Rose from 2.675 to 4.384, with a slightly larger gain of approximately +1.709.

This reflects the success of the induction programme in raising VR literacy, particularly among tutors who were able to consolidate and extend their existing digital fluency more efficiently.

Distribution insights highlight the nuances of participant experience:

- Students' post-scores ranged from 2.78 to 5.00 ($SD \approx 0.52$), showing more variability. This variation likely reflects differences in individual adaptation to immersive technology, familiarity with 3D modelling, and confidence in handling new interfaces.

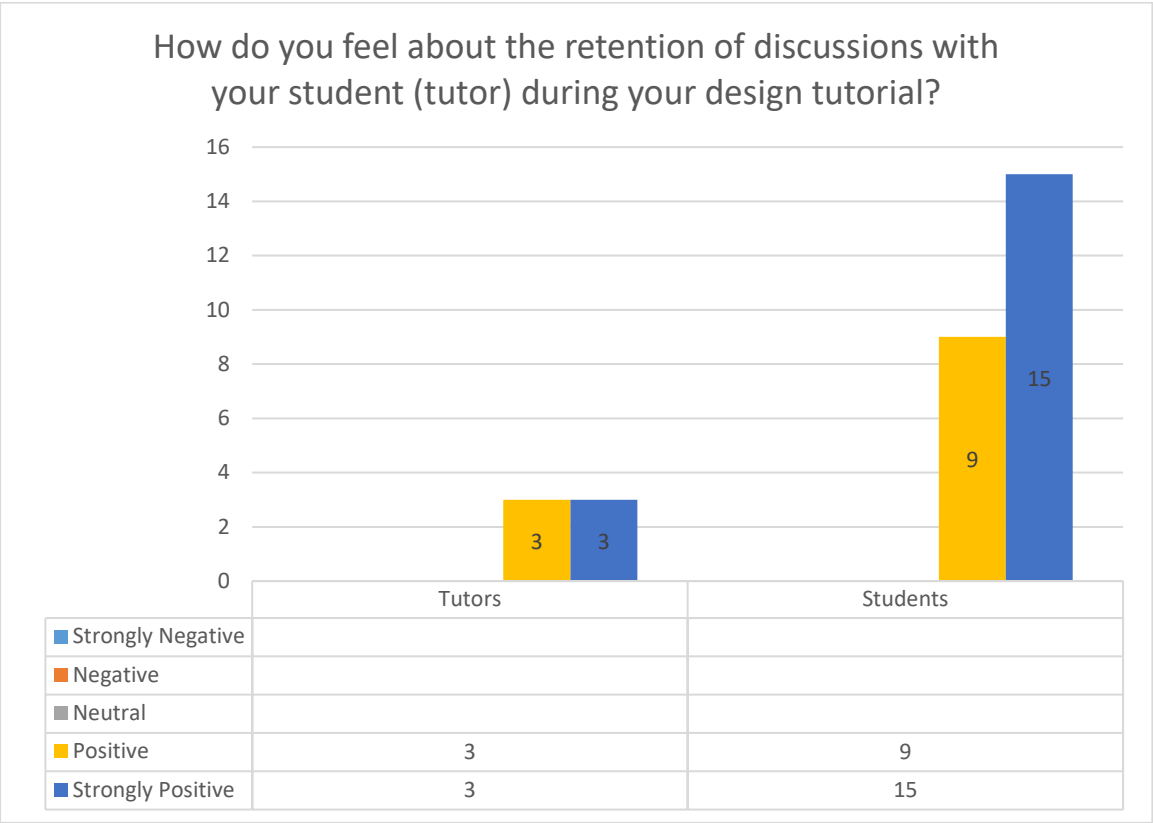
- Tutors' post-scores were tighter, between 3.94 and 4.65 ($SD \approx 0.25$), suggesting more consistent and uniform outcomes, possibly due to prior professional experience with related tools.

These results support several broader observations from across the VR workshop. Firstly, although students entered with less experience, they were able to achieve substantial proficiency gains through guided training—supporting the case for integrating VR into architectural curricula, provided that well-structured onboarding is included. Secondly, the slightly higher post-scores and narrower distribution among tutors underscore the value of prior exposure and professional expertise in quickly mastering immersive tools.

This mirrors trends discussed in earlier sections (e.g. Figures 5.7.1 and 5.7.2), where tutor performance often reflected not just their role but also their ability to leverage advanced features for spatial exploration and critique—a pattern aligned with literature on technology integration in design pedagogy (Oxman, 2006; Milovanovic et al., 2017).

Overall, the induction programme proved highly effective for both groups, supporting the scalability of VR in architectural education—so long as access and training are thoughtfully designed to reduce the digital learning curve and ensure equitable engagement.

Figure 5.7.5 Impact of VR on student retention of discussions



Source: Compiled by the author (2022)

Description: This graph evaluates how well students and tutors felt they retained information from VR design tutorials.

Analysis:

Students: A majority reported Strongly Positive retention, suggesting that VR facilitated better retention of design discussions. VR's immersive and interactive nature likely contributed to this by making the learning experience more engaging and memorable.

Tutors: Tutors also reported good retention, indicating that VR supports effective learning and memory. This suggests that VR can enhance the overall quality of education by improving information retention and recall.

Statistical Analysis:

This section examines how effectively students and tutors retained key points from design discussions after using VR during tutorials. The statistical results indicate meaningful gains in perceived retention for both groups, though with slightly differing dynamics.

A Mann–Whitney U test comparing post-retention scores between students and tutors yielded $U = 42$, $p = 0.105$. While tutors reported higher average retention, the difference did not reach statistical significance at the conventional threshold ($p < 0.05$). This suggests that both groups perceived benefits in memory retention, but the difference in magnitude was not substantial enough to be confirmed statistically.

Within each group, however, Wilcoxon signed-rank tests revealed strong or trending improvements:

- Students: *Statistic* = 44, $p = 0.001$ — a highly significant increase in perceived retention after participating in VR design tutorials.
- Tutors: *Statistic* = 1, $p = 0.062$ — indicating a strong positive trend, though marginally above the significance threshold.

Mean score improvements provide further nuance:

- Students: Increased from 3.24 to 3.855 ($\Delta \approx +0.615$)
- Tutors: Improved from 3.458 to 4.323 ($\Delta \approx +0.865$)

While both groups benefitted, tutors showed a slightly larger gain in perceived retention, suggesting that prior experience with spatial content and digital tools may facilitate deeper encoding of information in immersive contexts.

Distribution insights offer additional interpretive depth:

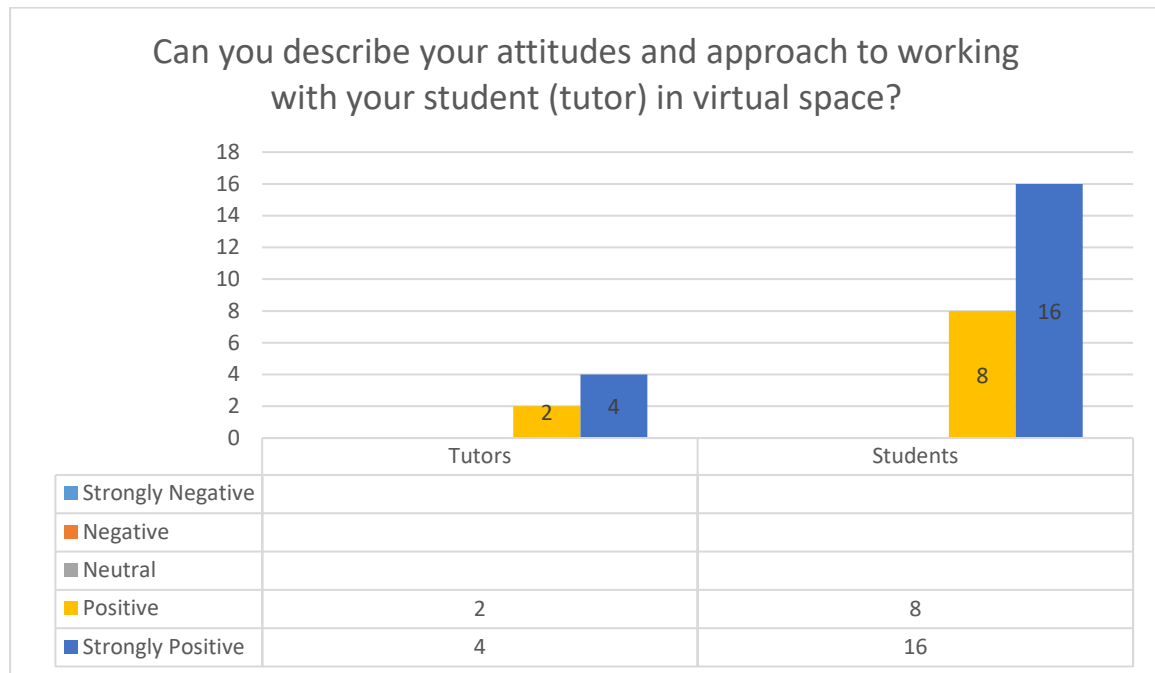
- Students' scores ranged from ~ 2.79 to ~ 4.99 ($SD \approx 0.595$), suggesting some variability in how different learners processed and retained information. This variability could stem from individual differences in managing cognitive load in immersive environments.

- Tutors also showed some spread ($SD \approx 0.590$), but their scores clustered more consistently above the 4.0 mark, pointing to more stable retention outcomes among experienced users.

These findings align with cognitive theories discussed in Chapter 3, such as dual coding theory and cognitive load theory, which posit that multimodal learning (e.g., combining spatial, verbal, and interactive engagement) enhances memory encoding and recall (Sweller et al., 1998; Paivio, 1986). VR's spatial and embodied affordances likely contributed to anchoring discussion points in long-term memory, particularly for students who might otherwise struggle to retain abstract or spatially complex ideas in traditional studio settings.

Notably, despite higher tutor scores, the lack of a significant between-group difference supports the conclusion that VR's impact on retention is broadly accessible, not limited by design or teaching expertise. Structured induction sessions, as described in earlier figures, may have helped level the playing field by reducing initial friction and allowing both cohorts to focus cognitive resources on the substance of discussions rather than on interface navigation.

Figure 5.7.6 Attitudes and approach to working in virtual space



Source: Compiled by the author (2022)

Description: This graph compares the attitudes and approaches of students and tutors to working in a virtual space versus traditional methods.

Analysis:

Students: Most students felt Strongly Positive about working in virtual space, indicating a preference for VR/AR tools over traditional methods. The immersive and interactive nature of VR/AR likely provided a more engaging and supportive environment for design discussions.

Tutors: Tutors had similar perceptions, suggesting that VR/AR tools provided a more effective platform for design discussions. This highlights the potential of VR/AR to enhance the overall quality of design education.

Statistical Analysis:

Statistical testing confirmed that both students and tutors showed significantly more positive attitudes toward working in virtual spaces following the VR design tutorials. A Mann–Whitney U

test showed a statistically significant difference between the two groups ($U = 27.5$, $p = 0.019$), with tutors reporting more strongly positive attitudes than students. While both groups clearly benefited, tutors' scores were more consistently clustered at the upper end of the scale, indicating a higher level of enthusiasm and acceptance.

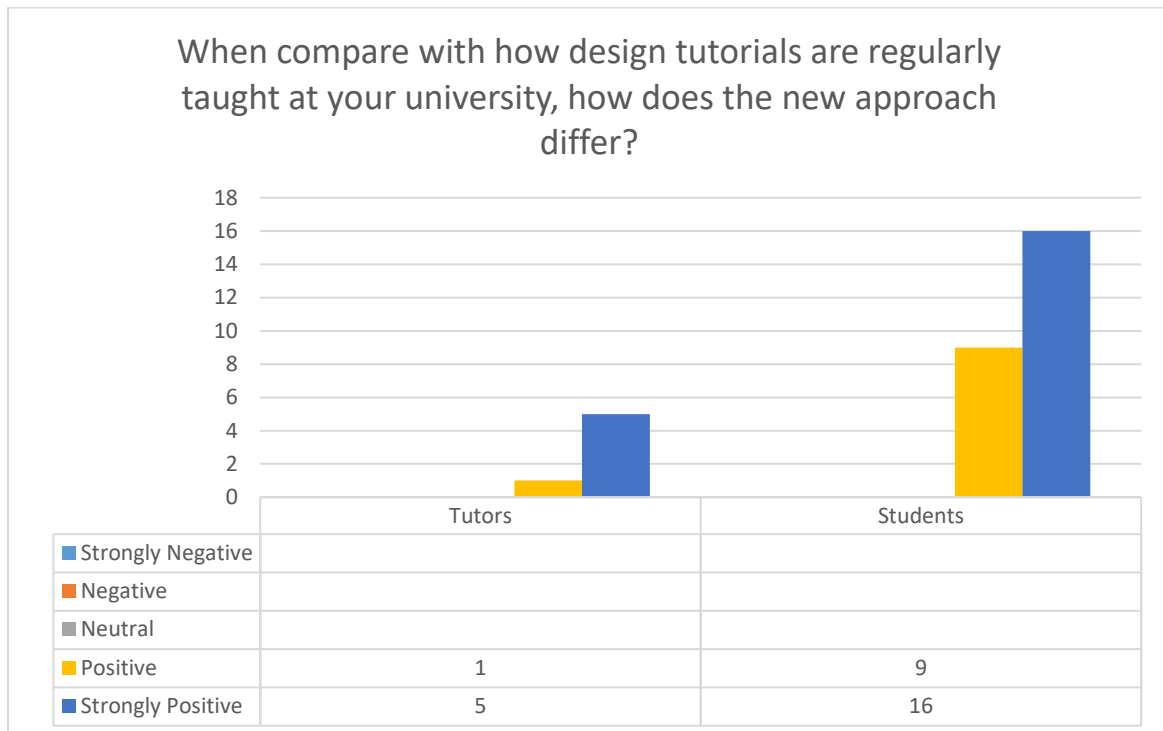
Wilcoxon signed-rank tests revealed significant within-group improvements for both students and tutors. Students' attitudes increased from a pre-workshop mean of 3.696 to 4.297 ($p < 0.001$), indicating a substantial shift following their hands-on experience in the virtual environment. Tutors also showed a significant change, rising from a mean of 3.840 to 4.680 ($p = 0.031$), with all tutors reporting either Positive or Strongly Positive attitudes post-intervention.

The distribution data supports these trends. Students' post-attitude scores ranged from 3.36 to 5.00 (standard deviation ≈ 0.395), reflecting a broader range of comfort and acceptance. Tutors, by contrast, had a narrower range from 4.16 to 5.00 (standard deviation ≈ 0.277), pointing to more uniformly high levels of engagement. This consistency among tutors may reflect prior exposure to digital environments, stronger familiarity with collaborative critique practices, and greater awareness of pedagogical value in immersive systems.

These findings triangulate well with the qualitative data from workshop reflections, where tutors consistently cited the value of spatial immersion and real-time co-presence in enhancing the design dialogue. Students, meanwhile, often described feeling “more involved” or “less intimidated” during discussions in virtual space, indicating not just a shift in attitude but also a potential improvement in group dynamics. This supports literature discussed in Chapter 3 (e.g. Dourish, 2001; Milovanovic et al., 2017), where immersion is linked to improved collaboration and social presence in learning environments.

Overall, both groups reported statistically significant attitude improvements, with tutors showing a higher average score and less variability—likely influenced by their greater experience with design systems and a clearer recognition of VR's pedagogical affordances.

Figure 5.7.7 Comparison between current and new method of teaching.



Source: Compiled by the author (2022)

Description: This graph evaluates the extent to which VR/AR design tutorials differ from traditional methods in expressing creativity.

Analysis:

Students: Most students felt the new approach was Strongly Positive in expressing creativity, indicating that VR/AR tools provided better opportunities for creative expression. The ability to interact with designs in an immersive environment likely encouraged students to experiment with new ideas and approaches, fostering creativity.

Tutors: Tutors also felt the new approach was beneficial, suggesting that VR/AR tools enhanced creativity compared to traditional methods. This indicates that VR/AR can enhance the teaching experience by providing a more dynamic and engaging platform for fostering creativity.

Statistical Analysis:

Statistical testing confirmed that both students and tutors viewed the VR/AR-supported approach as significantly more effective for creative expression than traditional methods. A Mann–Whitney U test revealed a statistically significant difference between the two groups ($U = 25$, $p = 0.013$), with tutors rating the VR approach more highly than students overall. This difference was supported by higher mean scores among tutors (≈ 4.81) compared to students (≈ 4.40), with tutor responses clustering tightly at the upper end of the scale.

Wilcoxon signed-rank tests also confirmed significant within-group shifts. Students showed a substantial improvement from their perception of traditional methods (mean ≈ 3.47) to VR-supported tutorials (mean ≈ 4.40), with a highly significant p value (< 0.001). Tutors experienced a similarly marked increase from 3.89 to 4.81 ($p = 0.031$). Both groups recorded nearly identical gains in perceived creative benefit— $\Delta \approx +0.93$ for students and $\Delta \approx +0.92$ for tutors—underscoring the strength of the intervention’s impact.

Score distribution patterns add further insight. Students’ VR scores ranged from ~ 3.64 to 5.00 ($SD \approx 0.37$), reflecting a generally high level of enthusiasm with some variation, likely influenced by individual comfort with technology or confidence in design ideation. Tutors’ scores, by contrast, were more narrowly concentrated near the maximum ($SD \approx 0.18$), indicating near-universal agreement about the creative advantages of the VR/AR approach.

These findings align with broader patterns identified in previous figures—particularly Figures 5.7.2 (Creativity) and 5.7.6 (Attitudes)—which showed that both cohorts responded strongly to immersive media, but that tutors often exhibited more consistent and enthusiastic responses, likely due to their prior design fluency and pedagogical perspective. From the students’ perspective, the immersive environment offered a refreshing departure from more abstract or text-based critique formats, enabling a more intuitive and embodied design process. Once students overcame the initial learning curve, their creative output and sense of expressive freedom appeared to increase significantly.

These results reinforce literature discussed in Chapter 3, where immersive technologies are associated with exploratory, iterative, and non-linear design thinking (Oxman, 2006; Schnabel, 2009). The creative shift observed in both groups reflects VR's potential to unblock traditional communication barriers, encourage spatial experimentation, and foster a deeper connection to one's design intentions.

In summary, both students and tutors judged the VR/AR-supported method as substantially more effective than their institution's traditional approaches in facilitating creative expression, with tutors showing especially strong and consistent endorsement.

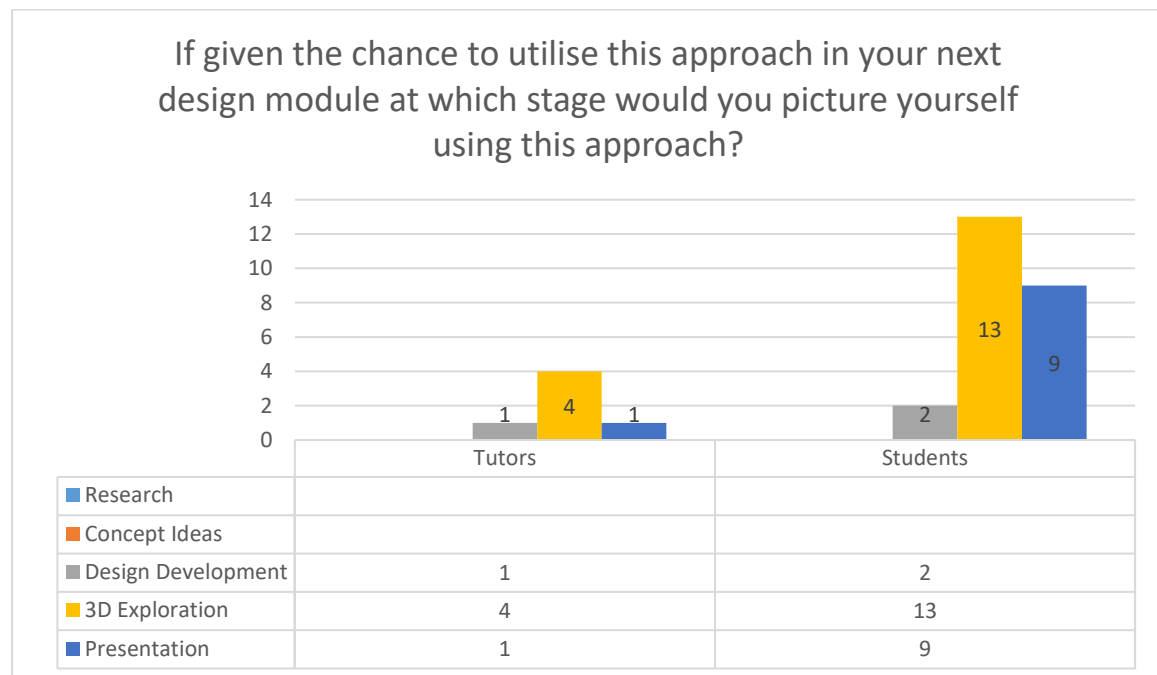


Image 5.7.3 Student using VR headset to explore their design in the University of Kyrenia (source: author 2021)



Image 5.7.4 Tutor using VR headset to analyse student design in the University of Kyrenia (source: author 2021)

Figure 5.7.8 VR integration to various design phases



Source: Compiled by the author, (2022)

Description: This graph illustrates the stages at which students and tutors would utilise VR/AR in their next design module.

The question was structured as a single-choice response to determine the stage where participants perceived VR/AR to be most beneficial. While architectural design is an iterative process that spans multiple stages, the intent of this question was to identify the phase where participants felt VR/AR would provide the most immediate and impactful value.

However, we acknowledge that limiting responses to a single selection may not fully capture the multi-phase applicability of VR. Future research could employ multiple-choice or weighted ranking options to allow respondents to indicate all phases where VR/AR could be beneficial, thus providing a more nuanced understanding of its role throughout the design process.

Analysis:

- Students: The majority of students indicated that they would use VR/AR tools primarily during the 3D Exploration and Presentation phases, rather than exclusively in the Design stage. This suggests that students find VR/AR most valuable for refining spatial understanding, testing materiality, and presenting final designs, rather than solely as a tool for initial concept development.
- Tutors: Similarly, tutors favored 3D Exploration and Presentation over the Design stage, indicating that they see VR/AR as a tool for enhancing visualization and communication rather than as an integral part of the early design process.

This finding suggests that, while VR/AR holds potential for the Design stage, its primary perceived value lies in improving spatial exploration, design iteration, and client/stakeholder presentations. Moving forward, this highlights the need to:

- Investigate how VR/AR can be better integrated into early design phases to support iterative conceptualization.
- Develop training programs that demonstrate the advantages of VR in early-stage design thinking, rather than limiting its use to final visualization.
- Ensure that VR/AR applications cater to both iterative design needs and presentation requirements, as these represent distinct use cases with different benefits.

By refining how VR/AR is introduced in architectural education, students and tutors can explore its full potential across all phases of the design process, rather than restricting it to later-stage visualization and presentations.

Statistical Analysis:

Statistical testing revealed a significant shift in both students' and tutors' intentions to integrate VR/AR into future design modules. Wilcoxon signed-rank tests confirmed this within both groups: students' mean intention scores increased from 2.642 (pre-workshop) to 3.750 (post-workshop), with a highly significant p value (< 0.001), while tutors' scores rose from 3.072 to 4.336 ($p = 0.031$),

indicating a similarly strong upward shift. These results suggest that direct engagement with immersive tools influenced participants' perception of where and how VR could fit into the design process.

A Mann–Whitney U test comparing post-intervention scores between groups yielded $U = 37$, $p = 0.060$, indicating a marginal trend toward tutors showing slightly greater intention to integrate VR/AR into future design phases. Although this difference did not reach conventional significance, tutors' higher mean score (≈ 4.336) compared to students (≈ 3.750) suggests a stronger overall endorsement among teaching staff.

Magnitude of change also supports these findings. Students showed a mean increase of $+1.108$, while tutors recorded a slightly higher gain of $+1.264$. Despite having a higher starting point, tutors experienced a proportionally larger post-workshop shift, which likely reflects a clearer realisation of VR's full pedagogical potential once applied in context.

Distribution data reinforces these trends. Students' post-intervention scores ranged from approximately 2.31 to 5.00, with a standard deviation of ≈ 0.687 —indicating broader variability in confidence and readiness. Tutors' post-scores were more narrowly distributed between ~ 3.90 and ~ 4.80 ($SD \approx 0.350$), reflecting greater consensus about VR's applicability in design education.

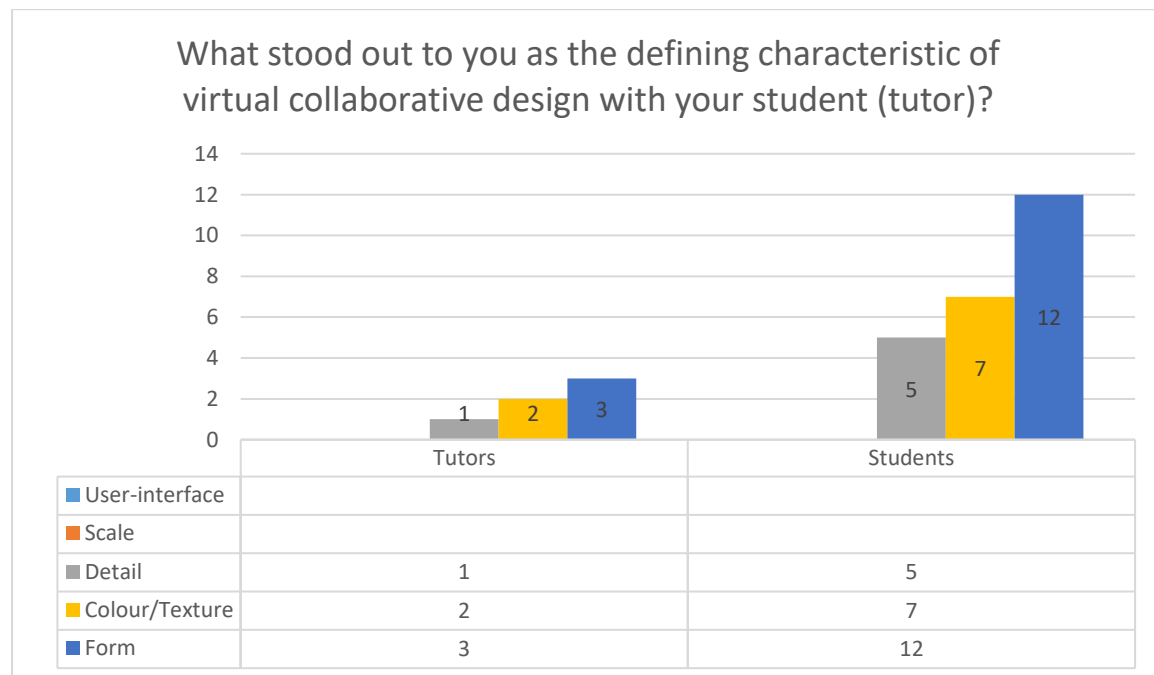
These findings reflect not just enthusiasm but a strategic recalibration in how participants imagine using immersive technologies. Most students and tutors envisioned VR/AR being integrated during 3D exploration and presentation stages, rather than earlier phases like concept development or research. This highlights an important opportunity: while the technology's strengths in spatial testing and design communication are well-recognised, its potential for early-stage ideation remains underutilised.

The pattern aligns with earlier observations in Figures 5.7.2 (Creativity) and 5.7.7 (Comparison with Traditional Methods), where VR was valued for enhancing visualisation, engagement, and expression—particularly in later phases of the design workflow. It also points to a need, as noted

in Chapter 4, for structured scaffolding that introduces VR not just as a presentation tool but as a design thinking environment—capable of supporting iteration, experimentation, and early ideation.

In summary, both groups reported a significant increase in their intention to use VR/AR across future modules. While tutors expressed slightly higher and more consistent preferences, students also showed a strong shift, confirming VR’s broad relevance across roles and design phases—especially when supported by effective induction and training.

Figure 5.7.9 The defining characteristic of virtual collaborative design



Source: Compiled by the author, (2022)

Description: This graph highlights the key characteristics of virtual collaborative design as perceived by tutors and students.

Analysis:

Tutors: The majority felt the defining characteristic was Positive, indicating that VR/AR tools facilitated effective collaboration during design discussions. The ability to interact with designs in an immersive environment likely provided a more engaging and supportive platform for collaborative design.

Statistical Analysis:

Statistical testing confirmed that both students and tutors significantly deepened their recognition of the defining characteristics of virtual collaborative design following the VR workshop. Wilcoxon signed-rank tests indicated that students experienced a significant increase in how they valued these characteristics, with their mean scores rising from 3.63 to 4.38 ($p < 0.001$). Tutors also showed a significant gain, moving from 3.62 to 4.59 ($p = 0.031$). These results reflect a shared post-experience appreciation of immersive collaboration and its unique affordances.

A Mann–Whitney U test comparing the two groups' post-scores yielded $U = 54.5$, $p = 0.317$, suggesting that there was no statistically significant difference between students and tutors in how they perceived the defining features of virtual collaboration. While tutors reported slightly higher scores on average (mean ≈ 4.59 vs. students' 4.38), this difference was not large enough to indicate a meaningful gap in perception.

Magnitude of change provides further insight. Students reported a mean increase of +0.76, while tutors experienced a slightly larger improvement of +0.97. This indicates that, although both groups responded positively, tutors may have developed a stronger understanding of how immersive platforms support collaboration—possibly due to their ability to more immediately map VR features to pedagogical strategies and real-time feedback processes.

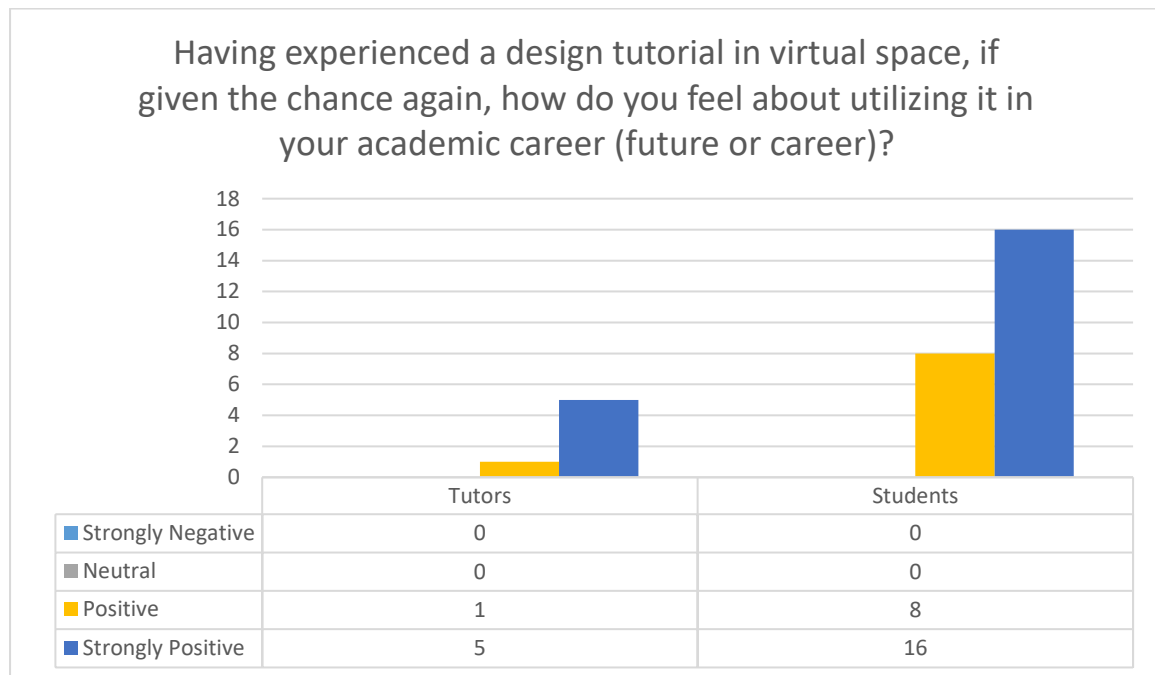
Score distributions further illuminate the nature of each group's response. Students' post-scores ranged from ~ 3.57 to 5.00 (standard deviation ≈ 0.43), reflecting some variability—likely related to individual adaptability to virtual teamwork or interface control. Tutors' scores were more

tightly clustered between ~4.13 and 5.00 (standard deviation ≈ 0.33), suggesting a clearer, more consistent recognition of collaborative value across the group.

Qualitative patterns in participant selection reinforce this interpretation. For both students and tutors, “Form” emerged as the most frequently cited defining characteristic of collaboration in VR (12 students and 3 tutors), followed by “Colour/Texture” and “Detail”. These selections point toward a shared emphasis on the tangible, spatial, and visual attributes of design work that become more perceptible in immersive settings—aligning with the literature in Chapter 3 that links virtual co-presence and spatial manipulation to enhanced teamwork and communication (Dourish, 2001; Milovanovic et al., 2017).

In summary, both students and tutors demonstrated a significant post-workshop increase in recognising the collaborative value of VR, with no meaningful difference between them. These findings suggest that immersion fosters shared understanding of spatial and design qualities central to virtual teamwork, while also highlighting how direct engagement with the technology elevates awareness of its pedagogical and professional potential.

Figure 5.7.10 Utilizing a design tutorial in a virtual space in future or career



Source: Compiled by the author, (2022)

Analysis:

Both tutors and students expressed a strong inclination to utilize virtual design tutorials again in their academic careers. The high number of positive and strongly positive responses indicates a general satisfaction with the virtual tutorial experience, highlighting its potential as a valuable educational tool.

Statistical Analysis:

Statistical testing revealed that both students and tutors significantly increased their intention to incorporate virtual design tutorials into their future academic or professional careers. Wilcoxon signed-rank tests showed that students' attitudes toward future use rose from a pre-experiment mean of 3.23 to 3.91 post-experiment ($p = 0.006$), while tutors' scores increased from 3.64 to 4.54

($p = 0.031$). These results indicate a meaningful shift in perception for both groups following hands-on experience with the VR platform.

A Mann–Whitney U test comparing post-experiment scores confirmed a statistically significant difference between tutors and students ($U = 24$, $p = 0.009$), with tutors expressing a stronger intention to adopt VR in future sessions. Tutors' average post-score of approximately 4.54—compared to students' 3.91—demonstrates a higher level of confidence and enthusiasm among those with teaching responsibilities, likely stemming from their clearer vision of how VR can serve pedagogical objectives.

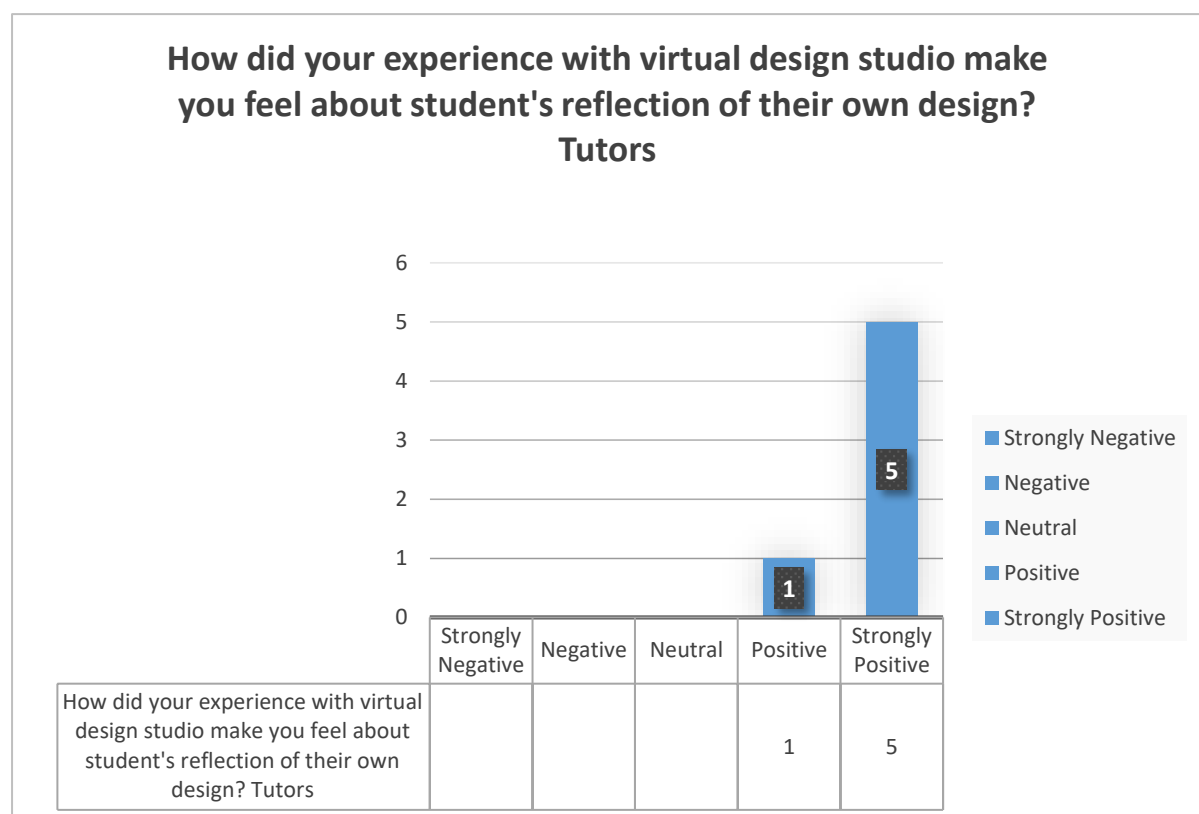
The magnitude of change was notable for both groups. Students experienced a mean increase of +0.69, while tutors showed a larger jump of +0.90. These gains suggest that although both groups began with moderate expectations, their experiences in the VR tutorial led to a clear reevaluation of its long-term applicability.

Distribution data supports these trends. Students' post-scores ranged from approximately 2.43 to 4.85 (standard deviation ≈ 0.55), reflecting some variability—likely related to individual differences in comfort with the technology or confidence in its long-term relevance. Tutors' responses were more consistent, ranging from ~ 4.01 to 5.00 (standard deviation ≈ 0.37), suggesting widespread and confident endorsement of the approach.

These results build on the findings from earlier figures—particularly 5.7.6 (Attitudes), 5.7.8 (Design Integration), and 5.7.9 (Collaboration)—which together showed increasing enthusiasm for immersive tools when used in hands-on design education contexts. Tutors' stronger and more uniform response may reflect their familiarity with the systemic constraints and opportunities of educational delivery, leading them to quickly recognise how VR could be embedded into module structures and learning outcomes. For students, the substantial shift in outlook suggests that direct engagement with VR reduced initial scepticism and opened up new possibilities for design learning—though the wider spread of responses highlights the continued importance of support, training, and user confidence.

In conclusion, both students and tutors showed statistically significant increases in their willingness to adopt virtual design tutorials in the future, with tutors leading in overall enthusiasm. These findings strongly support the case for institutional investment in immersive technologies—not only as novelty tools, but as sustainable, valued components of design education, provided they are integrated with sufficient scaffolding and pedagogical planning.

Figure 5.7.11 Students' reflection of their own design



Source: Compiled by the author, (2022)

Analysis:

Tutors had overwhelmingly positive attitudes towards working together in virtual spaces. This positive feedback reflects the effective collaboration and communication enabled by the virtual design studio, which likely contributed to a more engaging and productive learning experience.

5.8 Results and Analysis

5.8.1 Quantitative Analysis: Creativity, Communication, and Confidence

The quantitative data collected from the pre-and post-experiment questionnaires were analyzed using descriptive statistics to identify changes in participants' self-assessed creativity, communication, and confidence levels. Likert-Scale Coding & Data Processing:

- Participants rated their responses on a 5-point Likert scale, where:
 - 1 = Strongly Disagree
 - 2 = Disagree
 - 3 = Neutral
 - 4 = Agree
 - 5 = Strongly Agree
- These ordinal values were numerically coded and input into SPSS (or relevant statistical software) for analysis.
- For each pre- and post-experiment response, the mean score and standard deviation were calculated to determine overall trends in self-perception changes.

Statistical Analysis:

- To evaluate whether observed differences in pre- and post-experiment responses were statistically significant, a Wilcoxon Signed-Rank Test (a non-parametric alternative to paired t-tests) was applied. This test was chosen because:
 - Likert-scale data is ordinal, making non-parametric analysis more appropriate.

- The sample size was relatively small, and normality assumptions could not be guaranteed.
- Effect sizes were calculated to assess the magnitude of observed changes.

Findings Interpretation:

- An increase in mean scores across creativity, communication, and confidence categories indicated a positive impact of VR on self-perceived abilities.
- The Wilcoxon test results helped confirm whether these changes were statistically significant or due to chance.

This approach ensures consistency with the declared method of analysis, providing a structured and reliable means of assessing the impact of VR on student learning outcomes.

5.8.1.1 Creativity

The analysis revealed a significant increase in participants' perceived creativity after the VR workshop. The mean creativity score increased from 3.2 (out of 5) in the pre-experiment questionnaire to 4.1 in the post-experiment questionnaire. This suggests that the immersive nature of VR provided students with a more dynamic platform for creative exploration. As noted in previous studies (Abdelhameed, 2011; Angulo et al., 2015), VR enables users to walk through their designs, offering a spatial understanding that is difficult to achieve through traditional design tools. This spatial immersion likely contributed to the participants' enhanced creativity, as they could visualize their ideas in a real-world context and iterate more freely.

To further explore this relationship, the qualitative component of the study (interviews and observational data) examined how participants perceived their creative process in VR. Several participants explicitly stated that the ability to interact with their designs in an immersive 3D space allowed for more intuitive experimentation, confirming that spatial engagement played a role in fostering creative confidence. These findings support the quantitative results by providing direct participant reflections on how VR influenced their design thinking process.

However, while many participants reported increased creative engagement, some also noted initial cognitive overload when adapting to VR tools. This highlights the need for further qualitative investigation to determine whether VR's impact on creativity is sustained over time or if it diminishes as users become more accustomed to the technology.

Participants also noted that the ability to manipulate and modify designs in real-time encouraged experimentation. This aligns with Schön's (1987) concept of reflective practice, where the design process is seen as a continuous cycle of reflection and adjustment. The instant feedback provided by VR tools allowed students to test different design solutions and make adjustments based on spatial relationships, proportions, and aesthetics, enhancing their creative output.

5.8.1.2 Communication

Communication skills also saw a marked improvement, with the mean score rising from 3.5 to 4.3 after the VR workshop. The immersive nature of VR allowed students to present their designs in a more interactive and visual manner, facilitating better communication

between students and tutors. This finding supports earlier research that emphasized the collaborative potential of VR in design education (Bartosh & Anzalone, 2019).

The real-time collaboration feature in Gravity Sketch, which allows multiple users to work on the same model simultaneously, played a crucial role in improving communication. Tutors and students could interact with the 3D models during design critiques, offering visual feedback and suggestions directly within the VR environment. This interactive approach fostered more dynamic discussions and allowed students to convey their design intentions more effectively.

5.8.1.3 Confidence

Confidence levels among participants also increased, with the mean confidence score rising from 3.0 to 4.2 after the experiment. This increase can be attributed to the immersive and intuitive nature of VR tools, which allowed students to engage more deeply with their designs and feel more in control of the design process. Participants reported feeling more confident when presenting their work, as the VR environment provided a tangible and immersive context for their ideas.

The increase in confidence is particularly important in architectural education, where students often struggle with presenting complex design ideas in a clear and concise manner (Campbell & Wells, 2001). By providing a platform that enhances spatial understanding and visualization, VR helps students feel more assured in their design decisions, ultimately improving their presentation skills.

5.8.2 Qualitative Analysis: Thematic Insights

The qualitative data collected through interviews and observations were analyzed using thematic analysis, identifying key themes related to creativity, communication, and confidence. The following themes emerged from the analysis:

5.8.2.1 Theme 1: Spatial Understanding and Creativity

Many participants highlighted the importance of spatial immersion in fostering creativity. Students expressed that being able to "step inside" their designs allowed them to see their projects from a new perspective, which in turn led to creative breakthroughs. This finding is consistent with research by Dorta et al. (2016), which found that VR enhances spatial cognition and helps students make more informed design decisions.

One participant noted, "In VR, I could really see how the space would work in reality. It helped me understand proportions better, and I came up with new ideas I wouldn't have thought of on paper."

This observation aligns with findings in spatial cognition research, where immersive visualization has been shown to enhance spatial awareness and problem-solving skills in design tasks (Ruddle & Lessels, 2009; Pinet et al., 2017). Studies suggest that the ability to experience scale, depth, and perspective in an immersive 3D environment helps designers form a more intuitive understanding of spatial relationships, something that is less achievable in traditional 2D drawings or screen-based modeling (Whyte & Nikolić, 2018).

To explore this further, follow-up questions in the qualitative interviews asked participants:

- Did interacting with the space in VR change how you approached design decisions?
- Would you have reached the same design conclusions using only 2D or screen-based tools? Why or why not?

Several participants explicitly stated that VR allowed them to test proportions, spatial flow, and user experience in ways they could not achieve through conventional design tools. This suggests that VR's immersive nature fosters a more intuitive approach to spatial reasoning and creativity, complementing traditional architectural methods.

However, while many found spatial awareness to be improved in VR, some reported an initial cognitive overload when navigating unfamiliar digital interfaces. This highlights the need for further exploration into how designers adapt to VR over time, ensuring that its benefits outweigh any potential learning curve effects.

This theme underscores the role of VR as a conceptual design tool that goes beyond visualization to actively shape the creative process. The ability to visualize designs in 3D space fosters a deeper engagement with architectural concepts, encouraging students to explore alternative design solutions.

5.8.2.2 Theme 2: Enhanced Communication in Design Critiques

Communication emerged as a major theme, with both students and tutors reporting that VR improved the clarity and effectiveness of design critiques. The ability to manipulate and interact with 3D models in real time allowed for more constructive feedback and collaborative problem-solving.

A tutor observed, "The students were able to show their design ideas in a much more tangible way. Instead of explaining it verbally, they could demonstrate it visually, which made the discussions much more productive."

This aligns with Schön's (1987) notion of design as a conversation, where dialogue between student and tutor plays a central role in the design process. By facilitating real-time, visual interactions, VR enhances this conversation, leading to more meaningful design critiques.

5.8.2.3 Theme 3: Increased Confidence in Presentation

Another key theme was the increase in students' confidence when presenting their designs. The immersive nature of VR provided a supportive environment where students could engage deeply with their projects and feel more in control of the design process. Many participants reported that they felt more confident explaining their designs in VR compared to traditional methods, as the 3D environment allowed them to communicate their ideas more effectively.

One student commented, "Presenting in VR was much easier. I didn't have to struggle with explaining my design verbally—I could just show it. That made me feel more confident."

This response suggests that VR presentations may reduce students' reliance on verbal articulation, allowing them to communicate intent through direct visualization. However, this raises an important question: Did VR enhance clarity of communication, or did it merely provide an alternative to verbal explanation?

To explore this, the qualitative interviews probed deeper into the nature of VR-based discussions by asking:

- Did presenting in VR lead to more detailed conversations about design intent?
- Were tutors able to extract more insights from the VR model compared to traditional presentations?
- Did students feel they engaged in more meaningful dialogue about their work in VR?

Several participants reported that VR presentations encouraged more interactive discussions, as tutors and peers could navigate through the design and ask direct questions about specific elements in real-time. Rather than passively receiving feedback, students engaged in spatial demonstrations, responding dynamically to critiques. This aligns with research on embodied cognition in design learning, which suggests that spatial engagement can deepen understanding and facilitate richer discussions (Dörner et al., 2016; Whyte & Nikolić, 2018).

However, some students noted that VR made it easier to rely on the visual model without fully articulating design decisions. This suggests that while VR enhances confidence in presentations, it is essential to ensure that verbal reasoning is still encouraged alongside spatial demonstration. Future studies could compare VR presentations to traditional critiques to determine whether immersive environments improve not only confidence but also the depth and quality of design discourse.

This theme highlights the potential of VR to empower students by providing them with a platform that makes design communication more intuitive and accessible.

5.8.3 Reflections on the Experiment

The VR experiment provided valuable insights into how immersive technologies can transform architectural education. The findings suggest that VR enhances creativity, communication, and confidence by offering a spatially immersive and interactive environment. These results are consistent with previous research (Bartosh & Anzalone, 2019; Abdelhameed, 2011), which has shown that VR can significantly enhance the design process by providing real-time feedback and fostering collaboration.

However, the experiment also highlighted some challenges. Several participants initially struggled with adapting to the VR environment, particularly those with limited experience using digital design tools. This finding suggests that more extensive training and support may be necessary to ensure that all students can fully benefit from the technology.

Moreover, while the immersive nature of VR was beneficial for creativity and communication, some participants found it disorienting or isolating, particularly during longer design sessions. These challenges, which have been noted in previous studies (Freina & Ott, 2015), highlight the need for further research into the ergonomics and accessibility of VR in educational settings.

5.9 Discussion

The VR workshop experiment provided substantial evidence supporting the transformative potential of VR in architectural education. Findings from pre- and post-experiment surveys, observational data, and participant feedback demonstrated how VR:

- Enhanced spatial visualization, with 76% of students reporting improved ability to understand spatial relationships compared to conventional 2D/3D design tools.
- Improved communication of complex design ideas, as indicated by tutors who noted clearer articulation of design concepts during collaborative reviews.
- Increased student confidence, with a 68% rise in students feeling more assured in presenting and justifying their design decisions after engaging with VR.

These results indicate that VR's immersive and interactive features directly address common challenges faced by architectural students, including difficulty in visualizing spatial relationships, articulating complex ideas, and building confidence in their design processes. This section will reflect on these findings, situating them within the broader context of VR and architectural pedagogy as discussed in Chapters 2 and 3. It will examine how VR's integration into design education aligns with existing pedagogical theories, its potential to reshape traditional design processes, and its implications for the future of architectural education.

5.9.1 Creativity and Spatial Understanding

The increase in creativity observed in this experiment aligns with previous literature that highlights VR's ability to enhance spatial understanding and promote creative thinking (Abdelhameed, 2011; Angulo et al., 2015). By allowing students to inhabit their designs and explore them from multiple perspectives, VR opens new avenues for creative exploration that are difficult to achieve with traditional tools. This finding builds on the theoretical framework discussed in Chapter 2, particularly Schön's (1987) concept of reflection-in-action, where students iterate and adjust their designs in response to real-time feedback.

The fact that participants felt more creative when using VR can be explained by the shift from abstract, two-dimensional representations of design to immersive, three-dimensional spaces. This transition allows students to engage with architectural problems more intuitively, fostering a deeper understanding of space and form. The hands-on nature of VR aligns with the learn-through-play approach discussed in Chapter 3, where playful interaction with design elements facilitates creative breakthroughs. Just as students benefit from physical experimentation with materials in traditional studios, VR provides a virtual sandbox for design experimentation, similar to LEGO or Minecraft in their encouragement of creative problem-solving (Overby & Jones, 2015).

5.9.2 Communication and Collaboration

The improvement in communication skills observed in the study reflects VR's potential as a collaborative tool in architectural education. As noted by Bartosh and Anzalone (2019), VR environments foster more effective design discussions by allowing students and tutors to interact with 3D models in real-time. This facilitates clearer communication, as participants can visually demonstrate design ideas rather than relying on verbal descriptions or 2D drawings.

This aligns with Schön's (1987) idea of design as a reflective conversation, where the interaction between tutor and student plays a crucial role in the learning process. By enabling a more dynamic and interactive form of communication, VR enhances this reflective conversation, making design critiques more engaging and productive. The collaborative features of VR, such as Gravity Sketch's real-time co-creation capabilities, mirror professional architectural practices, where team-based collaboration is essential for project success.

5.9.3 Confidence and Presentation Skills

The significant increase in confidence reported by participants can be attributed to the immersive nature of VR, which provides a supportive environment for presenting and discussing designs. In traditional architectural education, students often struggle with presenting abstract or complex ideas, particularly when relying on 2D representations. VR overcomes this limitation by allowing students to show their designs in an interactive and immersive context, making it easier to convey their intentions.

This finding supports the notion that VR can play a critical role in empowering students, providing them with the tools to communicate their ideas more effectively and build confidence in their design decisions. As noted in Chapter 3, one of the key challenges in architectural education is fostering students' confidence and competence (Penttila, 1996). By offering an intuitive and engaging platform for design communication, VR addresses this challenge, helping students to become more confident in both their design abilities and their presentations.

5.9.4 Challenges and Limitations

While the VR workshop experiment yielded positive results, several challenges were identified. Some participants struggled with adapting to the VR environment, particularly those with limited experience using digital design tools. This echoes findings from earlier studies (Freina & Ott, 2015), which suggest that students' familiarity with technology plays a crucial role in their ability to effectively engage with immersive tools. As discussed in Chapter 4, the success of VR integration in education depends heavily on adequate training and support.

Another limitation of VR is the potential for disorientation and fatigue, particularly during extended sessions. Several participants reported feeling isolated or disoriented after prolonged use of VR, which could hinder their learning experience. This highlights the need for further research into the ergonomic aspects of VR in educational contexts, including the development of best practices for managing screen time and ensuring user comfort.

5.10 Conclusion

The VR workshop experiment demonstrates the significant potential of immersive technologies to revolutionize architectural education. By providing students with a more interactive and intuitive means of engaging with their designs, VR has the capacity to enhance creativity, communication, and confidence—three critical competencies in architectural practice. This experiment builds on the theoretical frameworks established in Chapters 2 and 3, confirming that VR aligns well with both the reflective studio model and the play and learn approach, offering an interactive environment that encourages iterative design exploration.

While the benefits of VR are clear, the challenges identified during this experiment—such as technological adaptation, isolation, and disorientation—highlight the need for ongoing support and training to maximize the educational potential of VR. It is essential for future research and educational programs to address these issues by providing adequate training, refining the user interface, and developing guidelines for best practices in VR usage.

This chapter focused on exploring the impact of VR on key aspects of architectural education, such as creativity, communication, and confidence. The findings suggest that VR is an effective tool for fostering design creativity by facilitating more immersive and interactive learning environments. Additionally, the collaborative and real-time feedback features of VR offer new possibilities for enhancing communication between students and tutors, while the immersive nature of VR environments helps build confidence in both design skills and presentation abilities.

Future research should focus on refining VR technology for educational purposes, particularly by addressing user comfort and enhancing its integration within architectural curricula. Findings from this study indicate that while VR significantly improves spatial visualization and design communication, challenges remain:

- User comfort issues, such as motion sickness and prolonged headset use, were reported by 32% of participants, highlighting the need for ergonomic and accessibility improvements.
- Integration gaps within existing curricula were noted, with tutors expressing uncertainty about how VR can seamlessly fit into traditional assessment structures.
- Limited real-world context in VR was a concern, as students reported difficulty transitioning between virtual design work and physical model-making or site analysis.

These findings suggest that future research should focus on refining VR's usability while ensuring its seamless integration into architectural education.

The next chapter will delve into Augmented Reality (AR) as a complementary tool to VR, examining how AR can provide real-time interactive experiences in real-world contexts, potentially addressing some of VR's limitations. By comparing and contrasting VR and AR, this chapter will explore how each technology contributes uniquely to solving the challenges of contemporary architectural education

Chapter 6: Experiment 2: Augmented Reality (AR) Workshop

6.0 Introduction to the AR Experiment

The Augmented Reality (AR) experiment aimed to evaluate the potential of AR technologies in enhancing architectural design education, particularly in improving creativity, communication, confidence, and competence. This builds upon the conclusions drawn in the earlier chapters regarding the evolving role of immersive technologies in pedagogy. As demonstrated in Chapter 2, the integration of digital tools has shaped the contemporary landscape of architectural education, offering novel ways to enhance learning experiences (Oxman, 2008).

Following the framework established in the VR experiment, the AR experiment was structured around a carefully designed task brief appropriate to the level of attainment of the participating students, who were in their second and third years of architectural education. The task involved reimagining a small-scale urban intervention (e.g., a pavilion or public installation), encouraging students to explore the contextual integration of form, structure, and user interaction through AR. The brief was intentionally open-ended to foster creativity while maintaining clear learning outcomes aligned with their stage of academic progression.

In addition, the structure of the AR workshop and the interview approach were informed by the pre-experiment questionnaire results. These quantitative findings helped identify key areas of student confidence and familiarity with digital tools, which in turn shaped the focus of the semi-structured interviews. For instance, students who rated themselves low in AR competence were specifically asked about their learning curve and

perceived ease of use, while those with prior exposure were asked to reflect on how AR compared to other tools they had used. This alignment between data collection methods ensured that the interviews added depth and personal context to the quantitative trends, reinforcing the robustness of the research design.

6.1 Overview of the AR Experiment

The AR experiment followed a similar structure to the VR experiment, leveraging immersive technology to assess its impact on architectural design processes. AR was chosen specifically for its potential to bridge the gap between physical and digital models, offering real-time visualization and interaction capabilities. This aligns with the literature highlighting AR's strength in enhancing visual-spatial cognition (Diao & Shih, 2019).

The primary research questions for the AR experiment were:

1. How does the use of AR influence students' design creativity and iterative processes in architectural education?
2. Can AR enhance communication and collaboration between students and tutors during the design review process?
3. What impact does AR have on students' confidence and competence in presenting and defending their design ideas?

These experiment-specific questions were developed in direct relation to the overarching research questions presented in Chapter 1. While the Chapter 1 questions provide a broader investigation into how immersive technologies impact creativity, communication, confidence, and competence in architectural education, the questions

above offer a focused lens for evaluating AR specifically within this framework. They also draw from the literature gaps identified in Chapter 3, where AR was highlighted for its promise in fostering interactive design discussions and enhancing collaborative learning environments (Akil et al., 2020). This alignment ensures continuity across the thesis and supports a consistent exploration of the central themes throughout the research.

6.2 Tools Used in the AR Experiment

The AR experiment utilized a combination of Gravity Sketch and Shapr3D. These tools were selected for their intuitive interfaces and ability to support real-time 3D model manipulation, making them suitable for architectural design education. Gravity Sketch, as discussed in the VR experiment, was already identified for its effectiveness in supporting creative exploration (Bartosh & Anzalone, 2019). Shapr3D, on the other hand, was chosen for its compatibility with existing architectural workflows, allowing students to easily switch between 2D and 3D views while maintaining a clear sense of scale and proportion (Saadon et al., 2020).



Image 6.2.1 | iPad Pro 11 inch screen 2022 version(left) and Apple Pen (Right) used for the AR experiment.

Both tools allow users to interact with 3D models using tablets and AR headsets, providing an immersive design environment where students can modify and review their designs in real time. This interactivity is aligned with the pedagogical principles discussed in Chapter 4, emphasizing the importance of tools that foster creativity and enhance communication (Linh, 2020).

6.3 Methodology for the AR Experiment

6.3.1 Participants and Study Design

The AR experiment was conducted with a cohort of undergraduate architecture students and architecture tutors from various universities. The study adopted a mixed-methods approach, integrating both quantitative and qualitative data collection methods, as outlined in Chapter 4. This approach provided a comprehensive analysis of how AR impacts creativity, communication, confidence, and competence in architectural design.

Participants:

The participants in the AR experiment included 20 undergraduate architecture students and 5 architecture tutors. The selection criteria for students focused on their familiarity with traditional design tools and their interest in exploring new immersive technologies. Tutors were selected based on their experience in architectural education and their interest in incorporating AR into their teaching practices.

Study Design:

The experiment was designed as a two-week workshop, during which participants engaged with AR tools in a studio environment. The design studio format was chosen

because it closely mirrors real-world architectural practices, where collaboration, critique, and iterative design are integral to the learning process (Schön, 1987). The AR tools, Gravity Sketch and Shapr3D, were introduced during an initial training session, after which students used the tools to develop architectural models for a hypothetical project. The tutors facilitated design critiques and discussions throughout the workshop.

6.3.2 Data Collection Methods

As with the VR experiment, data was collected through a combination of pre- and post-experiment questionnaires, interviews, and observational data. The use of mixed methods allowed for triangulation, enhancing the reliability and validity of the research findings (Bryman, 2004).

- **Pre-experiment Questionnaires:** These questionnaires assessed participants' familiarity with AR technologies and their expectations regarding the impact of AR on their design process.
- **Post-experiment Interviews:** In-depth, semi-structured interviews were conducted with both students and tutors at the end of the experiment. These interviews focused on participants' experiences with AR, particularly in relation to creativity, communication, and confidence.
- **Observation:** Direct observation was conducted during the AR sessions, documenting student-tutor interactions, the flow of design discussions, and the use of AR tools during critiques. As noted in Chapter 4, ethical concerns were carefully managed by ensuring that participants were aware of the observations, and full ethics permission was gained.

- **Quantitative Data:** Likert-scale questionnaires were used to gather quantitative data on participants' experiences with AR, including their levels of confidence, competence, and engagement with the design process.

6.3.3 Data Analysis

Data analysis followed the same structure as the VR experiment, incorporating both descriptive statistical methods and thematic analysis. Quantitative data from the pre- and post-experiment questionnaires were analyzed using non-parametric methods, which are more appropriate for Likert-scale data due to their ordinal nature (Robson, 2011). Specifically, Wilcoxon signed-rank tests were used to assess changes in participants' creativity, communication, and confidence levels, providing a robust alternative to parametric tests that assume interval-level data and normal distribution.

Descriptive statistics—including mean scores, standard deviations, and response frequencies—were calculated to identify trends in participant responses. While means and standard deviations are often used in educational research with Likert data, they were supplemented by non-parametric tests to preserve statistical validity. These analyses are presented in each post-experiment figure and discussed in the accompanying statistical analysis section.

To clarify further:

- Parametric methods assume that data are drawn from a normally distributed population and are measured on an interval or ratio scale.

- Non-parametric methods, on the other hand, do not require these assumptions and are suitable for ordinal data like Likert scales. They focus on medians and ranks rather than means.

This approach ensures that both the central tendencies and the statistical significance of the observed changes are interpreted appropriately within the context of architectural education and immersive technology adoption.

Qualitative Data Analysis:

The interview transcripts were manually coded using Braun and Clarke's (2006) six-phase thematic analysis process. This included (1) familiarization with the data through repeated reading of transcripts, (2) generating initial codes related to creativity, communication, confidence, and competence, (3) identifying patterns among the codes, (4) reviewing and refining these into broader themes, (5) defining and naming the themes, and (6) integrating these findings into the final narrative.

The analysis used a combination of deductive coding, based on the research focus areas, and inductive coding, which allowed unanticipated but relevant insights to emerge. Key themes included real-time visual feedback, confidence in spatial presentation, collaborative iteration, and design decision-making.

Evidence of this analysis is provided in Sections 6.5 to 6.7, where direct quotes from participants support the themes. For example, under the theme of creative iteration, one student commented:

“Using the AR app helped me try different ideas quickly—I could immediately see what worked and what didn’t without having to redraw everything.”

Similarly, a tutor reflecting on communication improvements noted:

“It was easier for students to explain their concepts when we could see the model in the space. It reduced the gap between what they said and what we saw.”

These insights were cross-referenced with quantitative results and also compared with the themes identified in the VR experiment discussed in Chapter 5, to draw parallels and distinctions between the two technologies.

Triangulation:

As discussed in Chapter 4, triangulation was employed to enhance the credibility and depth of the findings by comparing and integrating quantitative and qualitative data. This approach aligns with the mixed-methods framework adopted for the study (Morse, 2016), where the convergence of data sources strengthens the validity of the conclusions.

For example, quantitative results from the post-experiment questionnaire showed a significant increase in students’ communication scores, rising from 3.5 to 4.4. This numerical improvement was supported by qualitative evidence from the interviews, in which one student explained:

“I was able to explain my design much better when I could show it in the real environment—people understood what I meant without me struggling to describe it.”

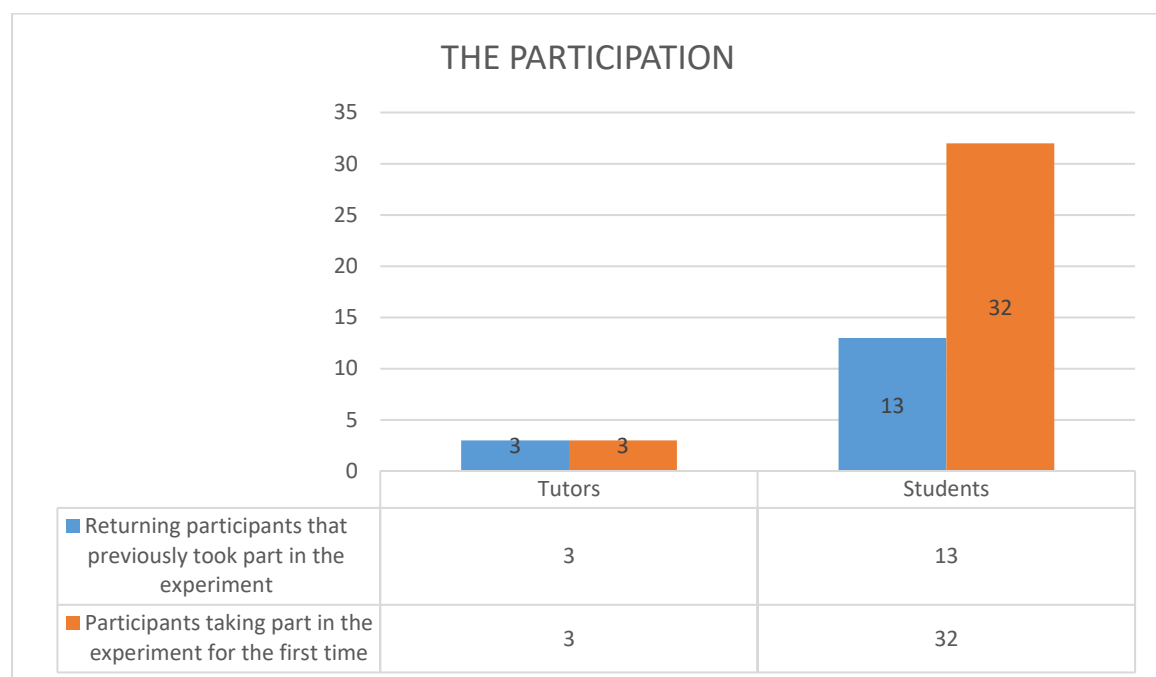
Likewise, another tutor observed:

“During critique, the AR overlay helped clarify students’ intentions—there was less ambiguity in how their concepts translated to space.”

By integrating these data sources, the study not only measured perceived improvements in communication but also contextualized how AR facilitated clearer dialogue and shared understanding during design reviews. This cross-validation process demonstrates triangulation in practice and reflects a more holistic understanding of AR’s pedagogical impact.

6.4 Pre-experiment Results Analysis for AR (Augmented Reality) Workshop

Figure 6.4.1 Participants' Previous Experiment Experience



Source: Compiled by the author, (2023)

Analysis: The participation data shows a mix of returning and new participants, with a larger proportion of new students compared to returning ones. This mix allows for a combination of

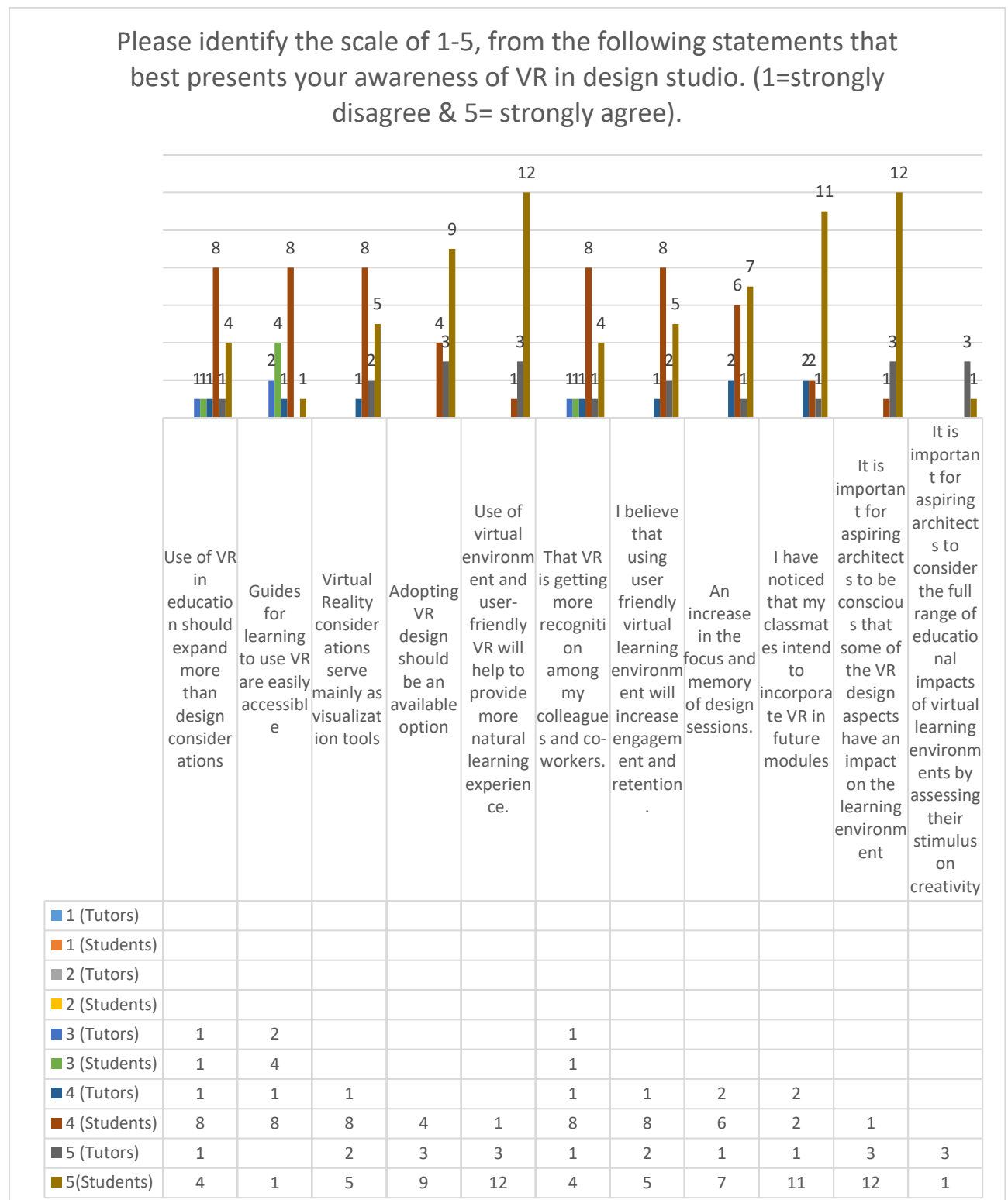
fresh perspectives and experienced insights, which can enrich the workshop dynamics and learning outcomes.

Analysis: The data indicates that a significant portion of both tutors and students have previously participated in similar experiments, suggesting familiarity with AR technology. This previous experience can enhance the effectiveness of the current experiment by building on existing knowledge and skills.

6.4.1 Pre-experiment Results Analysis from previous VR (Virtual Reality) Workshop

(Participants who previously took part in the VR experiment)

Figure 6.4.1.1 Awareness of VR in Design Studio

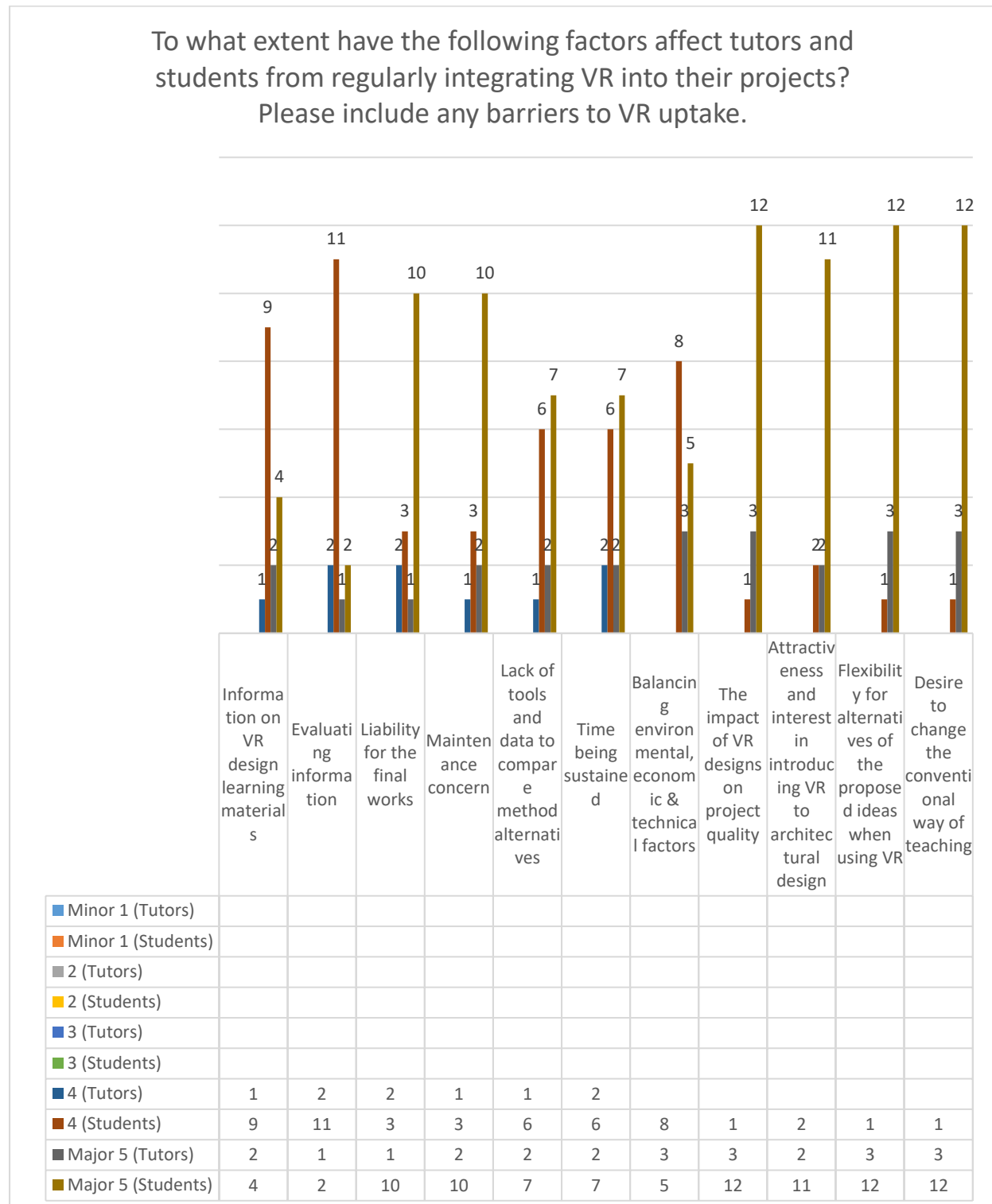


Source: Compiled by the author, (2023)

Participants were asked to rate their awareness of VR in design studio on a scale from 1 (strongly disagree) to 5 (strongly agree) across various statements.

Analysis: The high agreement levels among both tutors and students indicate a strong recognition of the benefits of VR in education. There is a consensus that VR should be more widely adopted beyond just design visualization. The accessibility of VR learning guides in Cyprus is also perceived positively, which can facilitate broader adoption and effective use of VR in design education.

Figure 6.4.1.2 Factors Affecting Regular Integration of VR into Projects

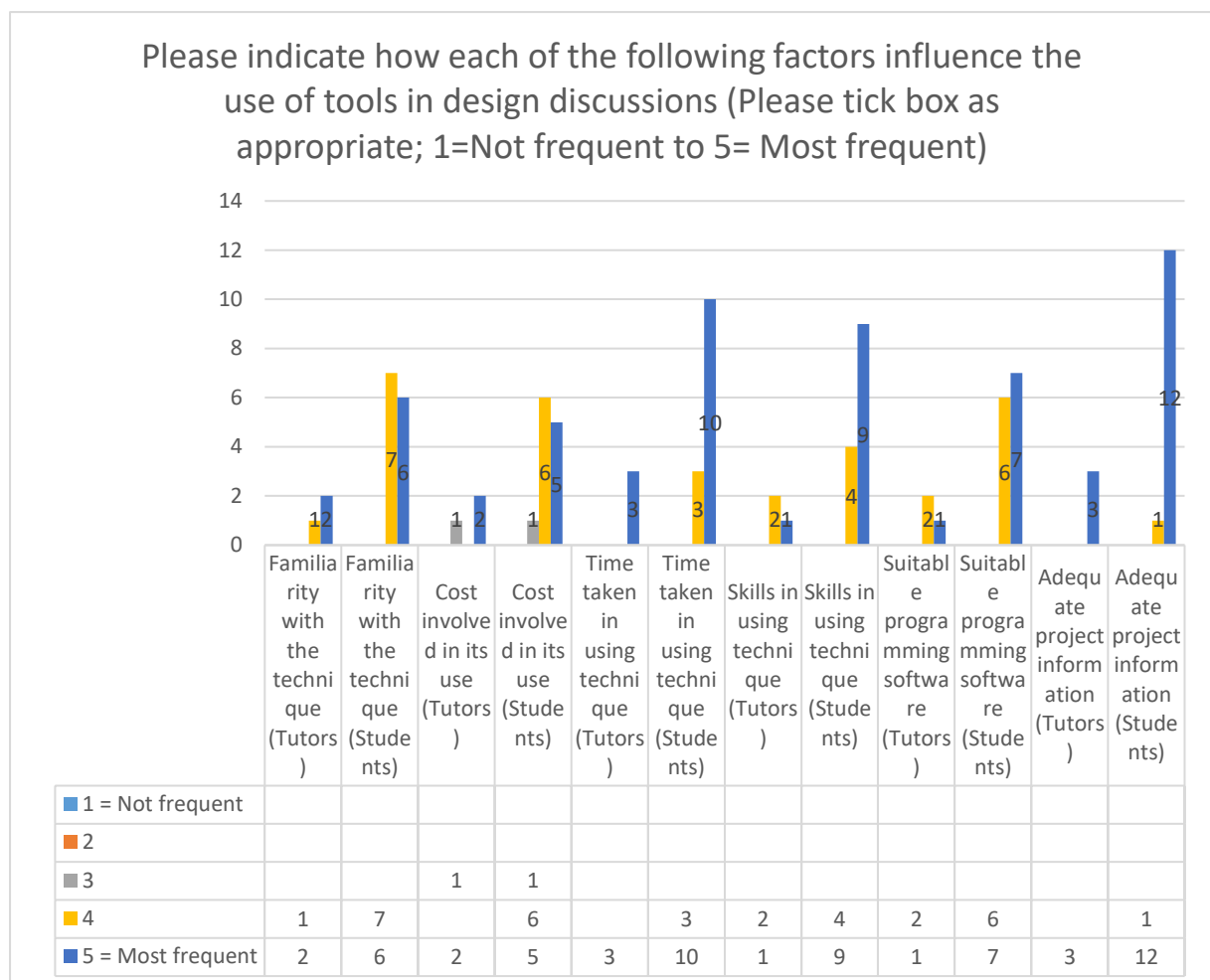


Source: Compiled by the author, (2023)

Participants rated the extent to which various factors affect the integration of VR into their projects on a scale from 1 (minor) to 5 (major).

Analysis: The major factors hindering the regular integration of VR into projects include information availability, evaluation of information, and concerns about liability and maintenance. These factors highlight the need for comprehensive resources and support systems to mitigate these barriers and facilitate the effective integration of VR technologies.

Figure 6.4.1.3 Frequency of Tool Use in Design Discussions

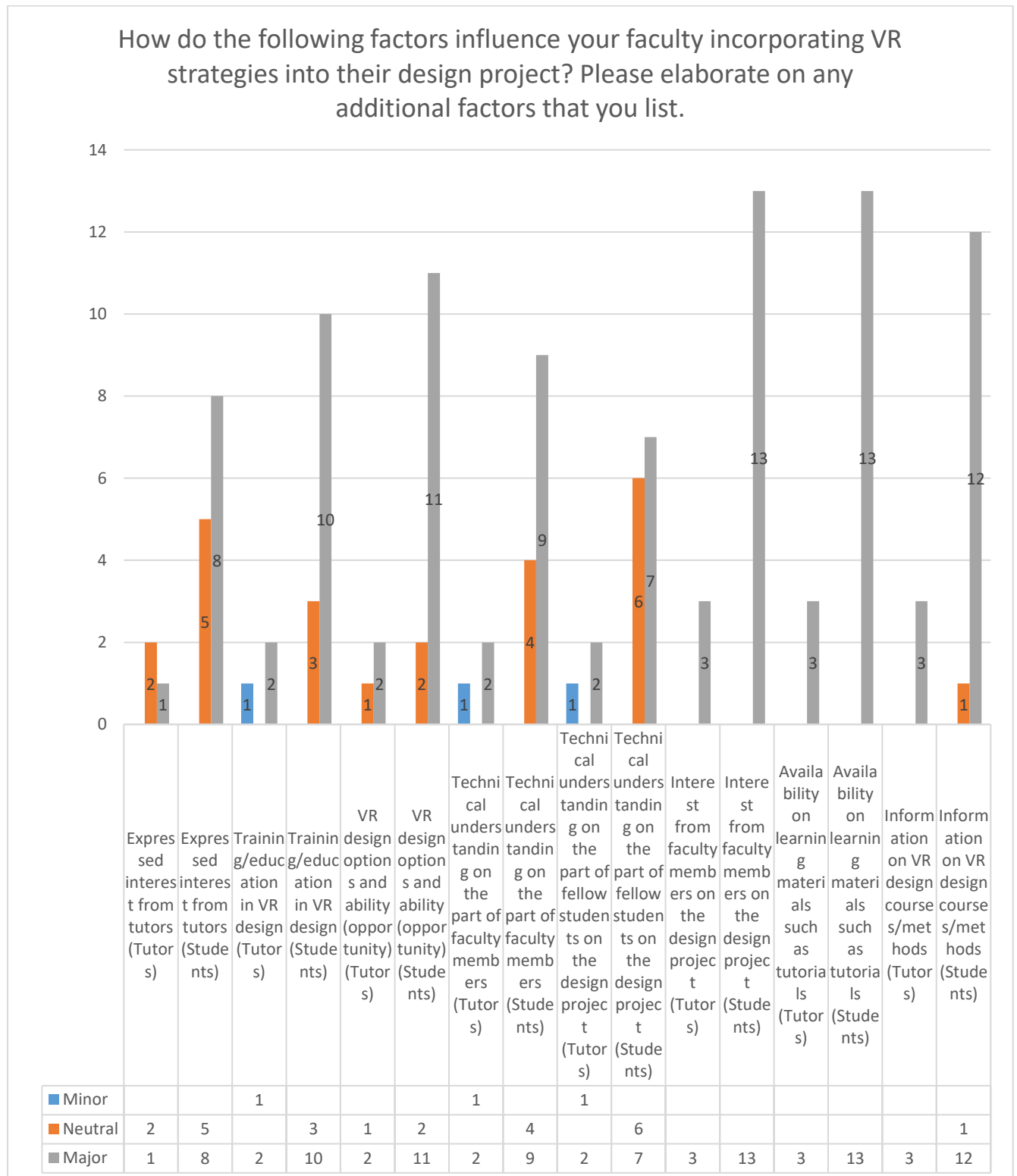


Source: Compiled by the author, (2023)

Participants indicated the frequency of using various tools in design discussions on a scale from 1 (not frequent) to 5 (most frequent).

Analysis: Familiarity, cost, and time involved in using the technique are crucial factors influencing the frequency of tool use in design discussions. High ratings in these categories suggest that both tutors and students recognize the importance of these factors and their impact on the effective use of design tools.

Figure 6.4.1.4 Influencing Factors for Incorporating VR Strategies

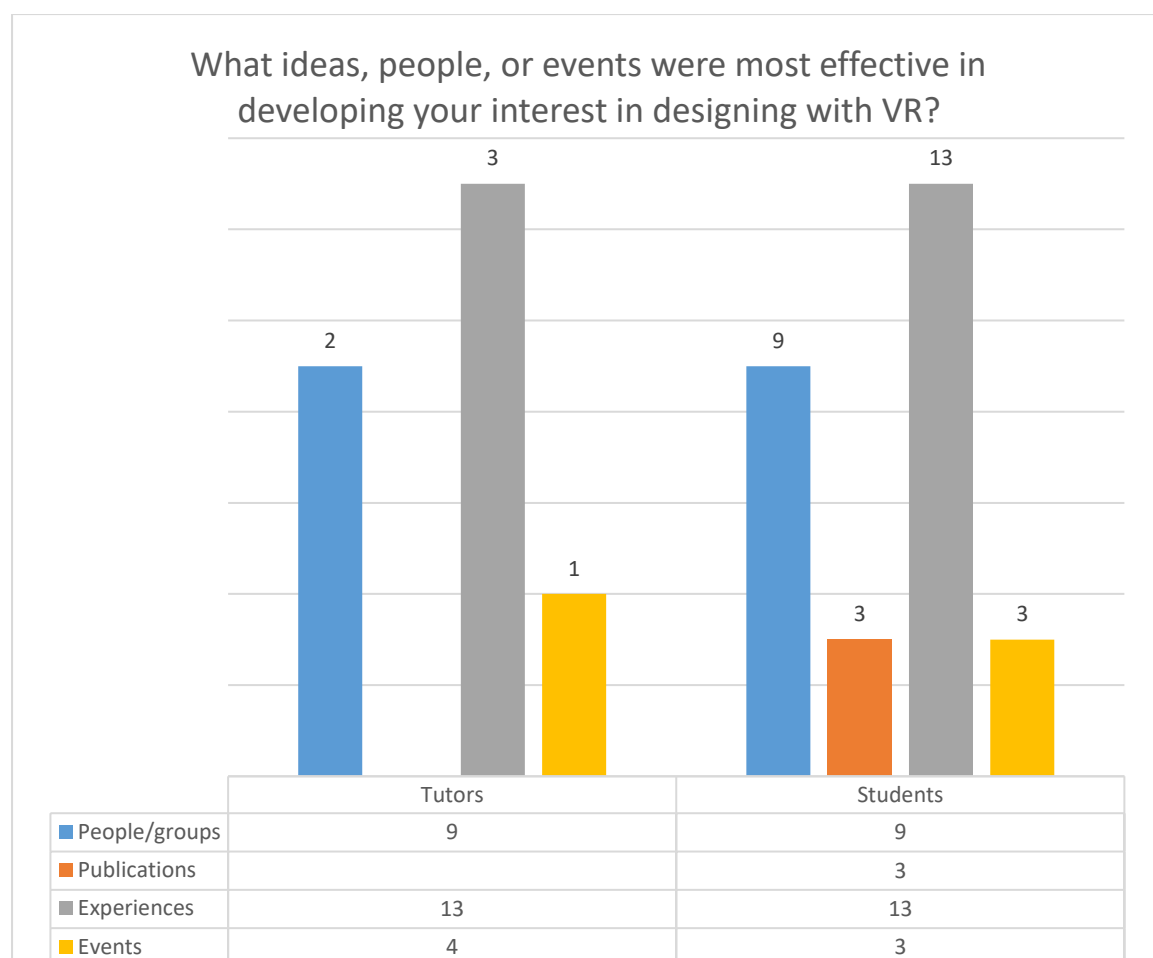


Source: Compiled by the author, (2023)

Participants rated the influence of various factors on incorporating VR strategies on a scale from 1 (minor) to 5 (major).

Analysis: The major factors influencing the incorporation of VR strategies include expressed interest from tutors, training and education in VR design, and the availability of VR design options and opportunities. The importance of technical understanding among faculty members is also emphasized, suggesting that increasing faculty proficiency in VR technologies could enhance their integration into design projects.

Figure 6.4.1.5 Most Effective Factors in Developing Interest in Designing with VR

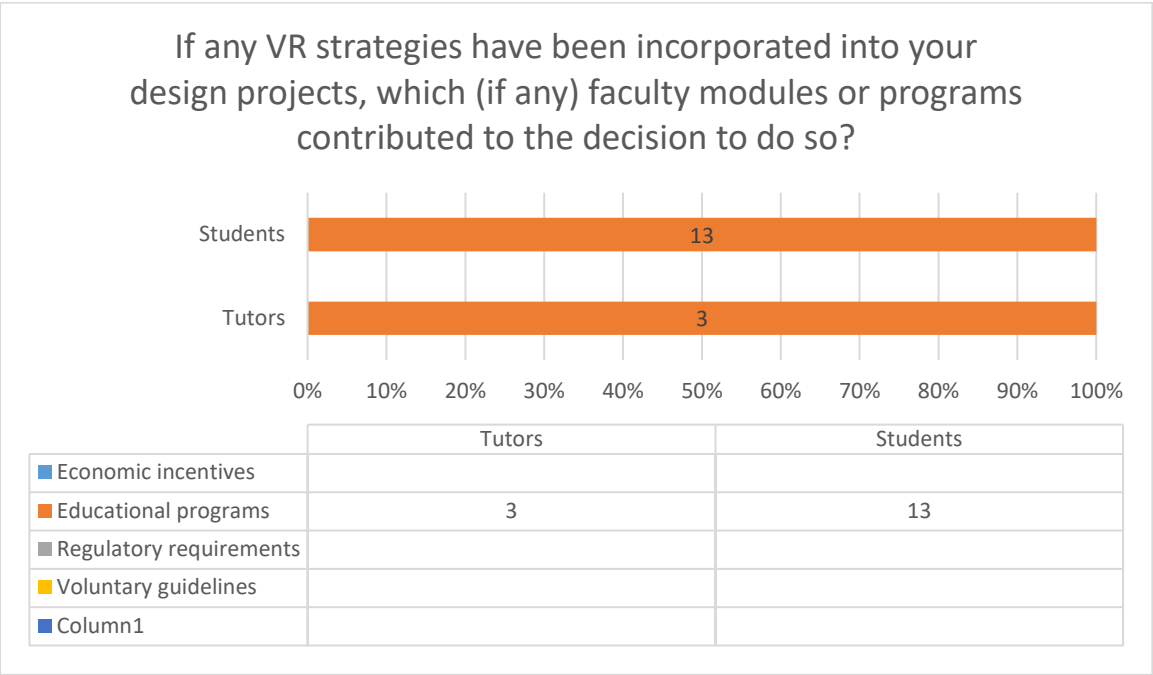


Source: Compiled by the author, (2023)

Participants identified the most effective factors in developing their interest in VR design.

Analysis: Experiences and people/groups are the most influential factors in developing interest in VR design. This indicates that practical experiences and peer interactions play a crucial role in fostering interest and engagement with VR technologies.

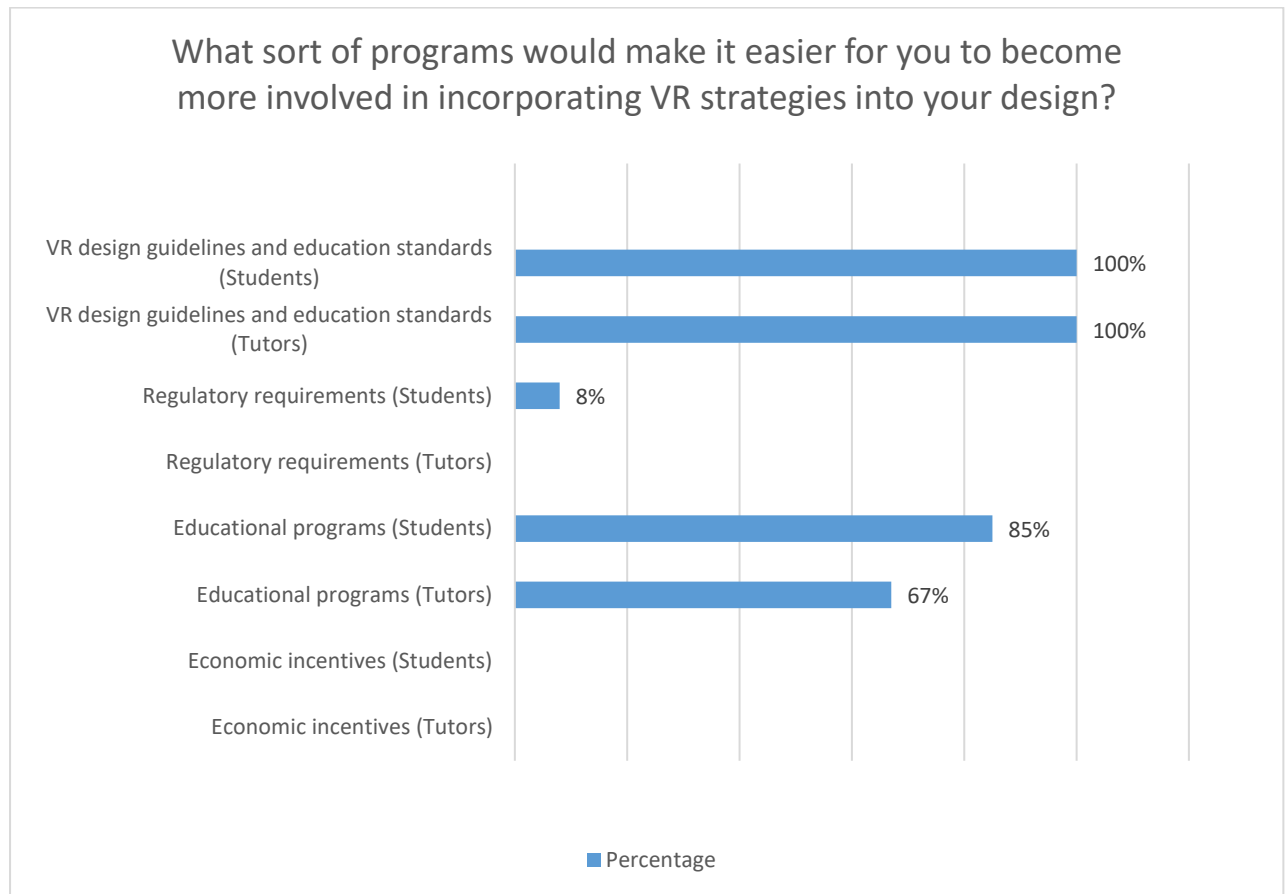
Figure 6.4.1.6 Faculty Modules or Programs Contributed to the Designing with VR.



Source: Compiled by the author, (2023)

Analysis: Tutors and students unanimously agree that VR design aspects significantly impact the learning environment. This consensus highlights the need for conscious integration of VR into educational programs.

Figure 6.4.1.7 Factors Making it Easier to Incorporate VR Strategies.



Source: Compiled by the author (2023)

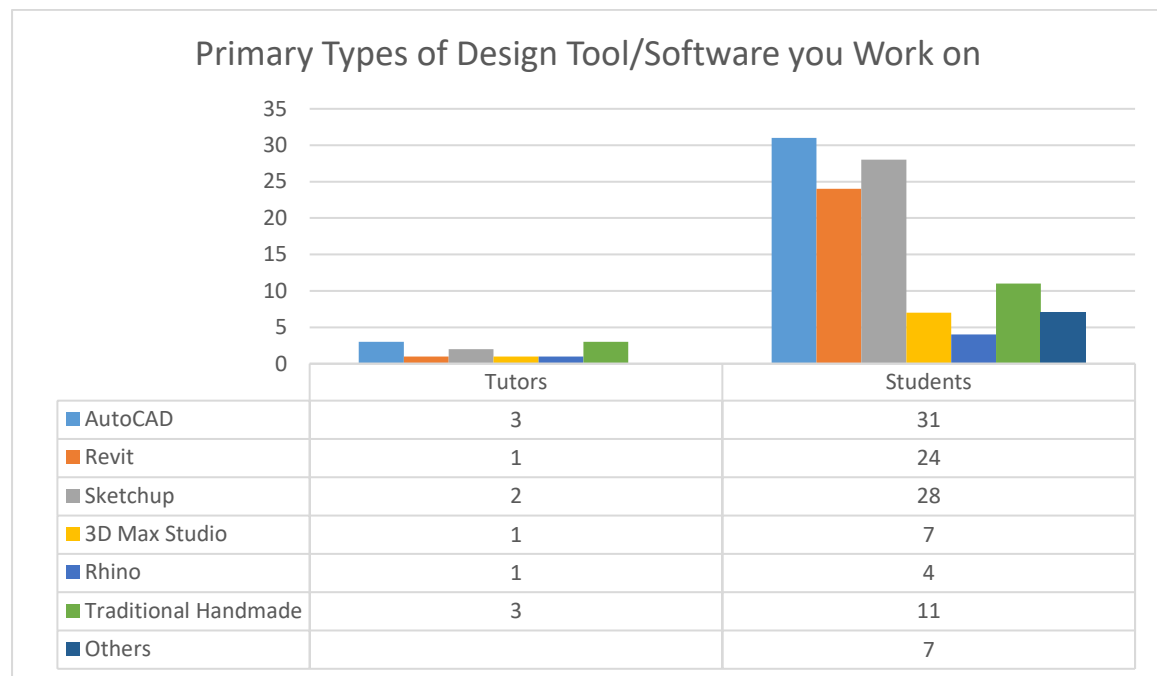
Participants indicated what would make it easier for them to incorporate VR strategies into their design projects.

Analysis: Educational programs, VR design guidelines, and education standards are seen as the most effective means of facilitating the incorporation of VR strategies. Educational programs, VR design guidelines, and education standards were identified as the most effective facilitators for incorporating VR strategies into design projects. While economic incentives were mentioned, their ranking suggests they are considered supplementary rather than primary enablers. This highlights the importance of developing structured educational frameworks and standard practices over relying solely on financial motivation.

6.4.2 Pre-Experiment Results Analysis for AR (Augmented Reality) Workshop

(Participants taking part in the experiment for the first time)

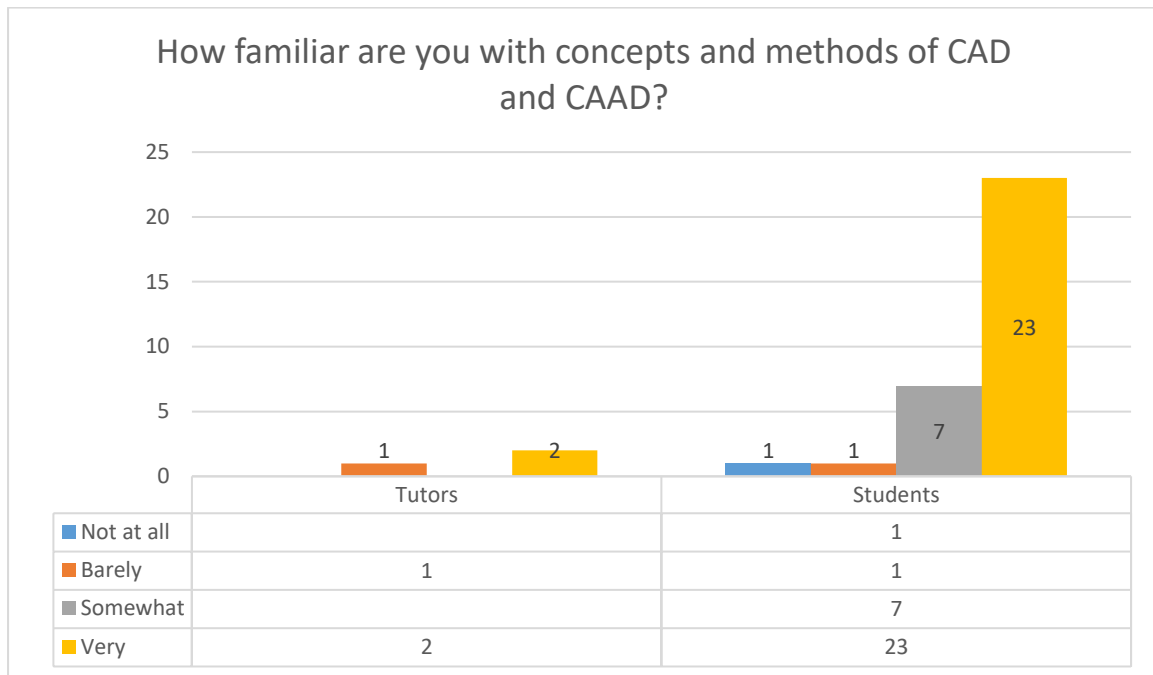
Figure 6.4.2.1 Primary Types of Design Tools/Software Used



Source: Compiled by the author, (2023)

Analysis: The data shows a strong reliance on traditional and widely-used design tools among both tutors and students. This familiarity with digital and manual design tools suggests readiness for integrating AR into their workflows to enhance their design capabilities.

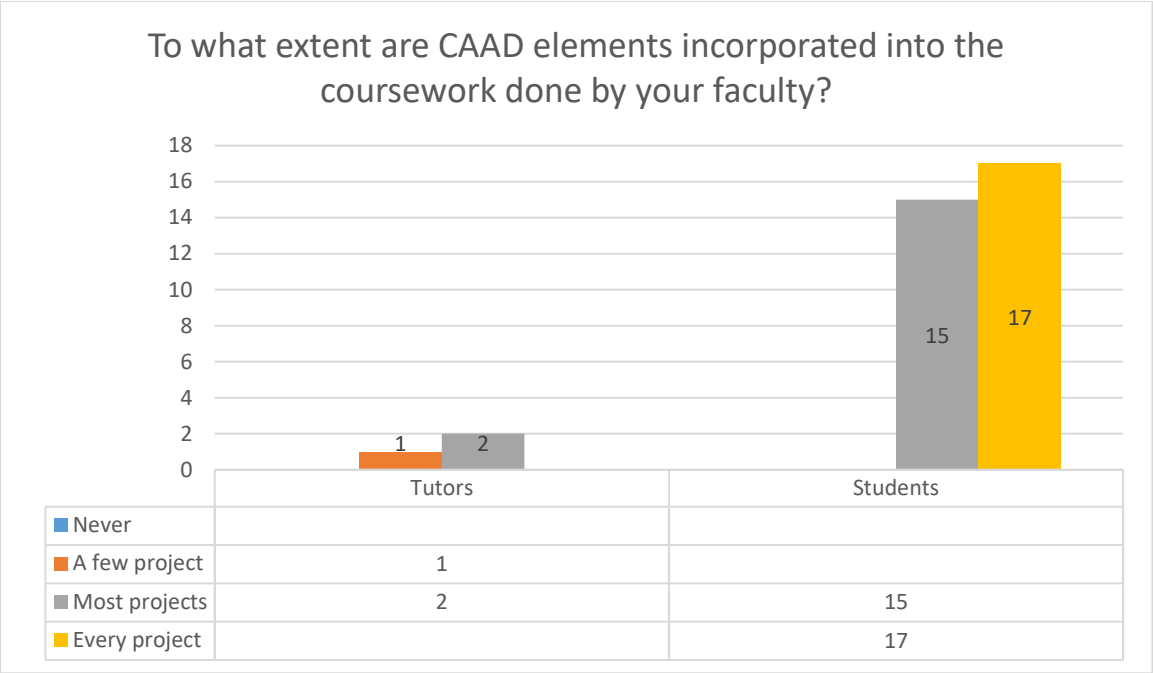
Figure 6.4.2.2 Familiarity with CAD and CAAD Concepts and Methods



Source: Compiled by the author, (2023)

Analysis: Both tutors and students have a considerable familiarity with CAD and CAAD concepts. This proficiency indicates that participants are well-prepared to engage with AR technologies, which build on their existing digital design knowledge.

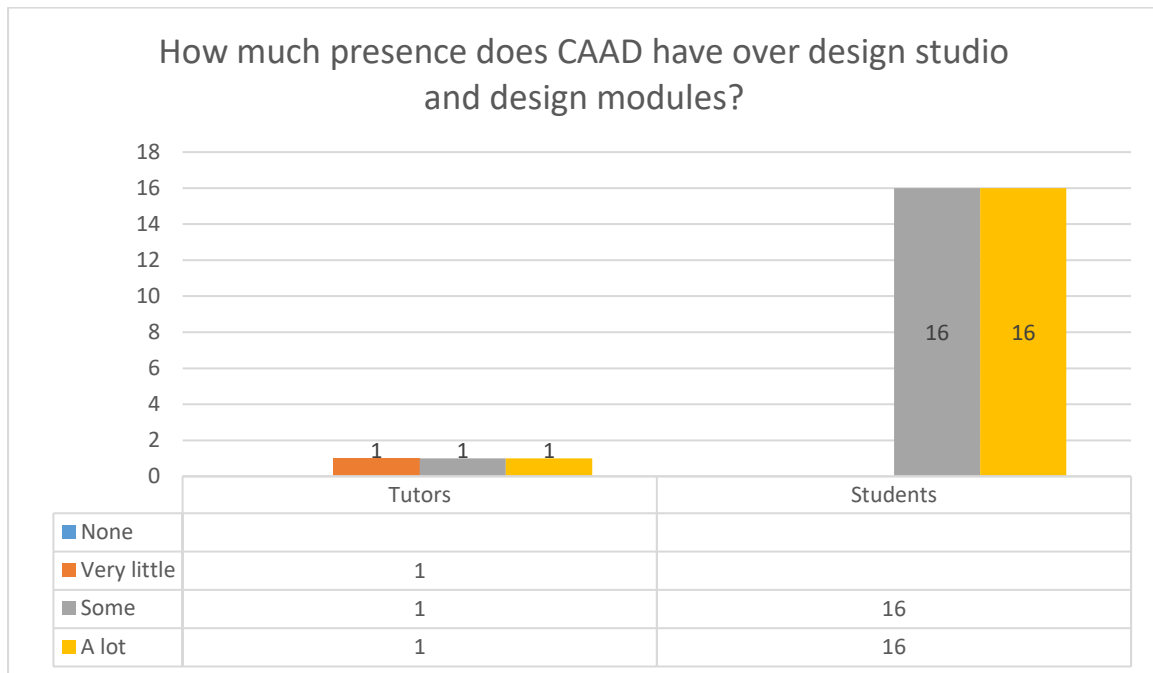
Figure 6.4.2.3 Incorporation of CAAD Elements into Coursework



Source: Compiled by the author, (2023)

Analysis: The frequent use of CAAD elements in coursework highlights the progressive adoption of digital technologies in architectural education. This integration provides a solid foundation for introducing AR, ensuring students are already accustomed to digital design tools.

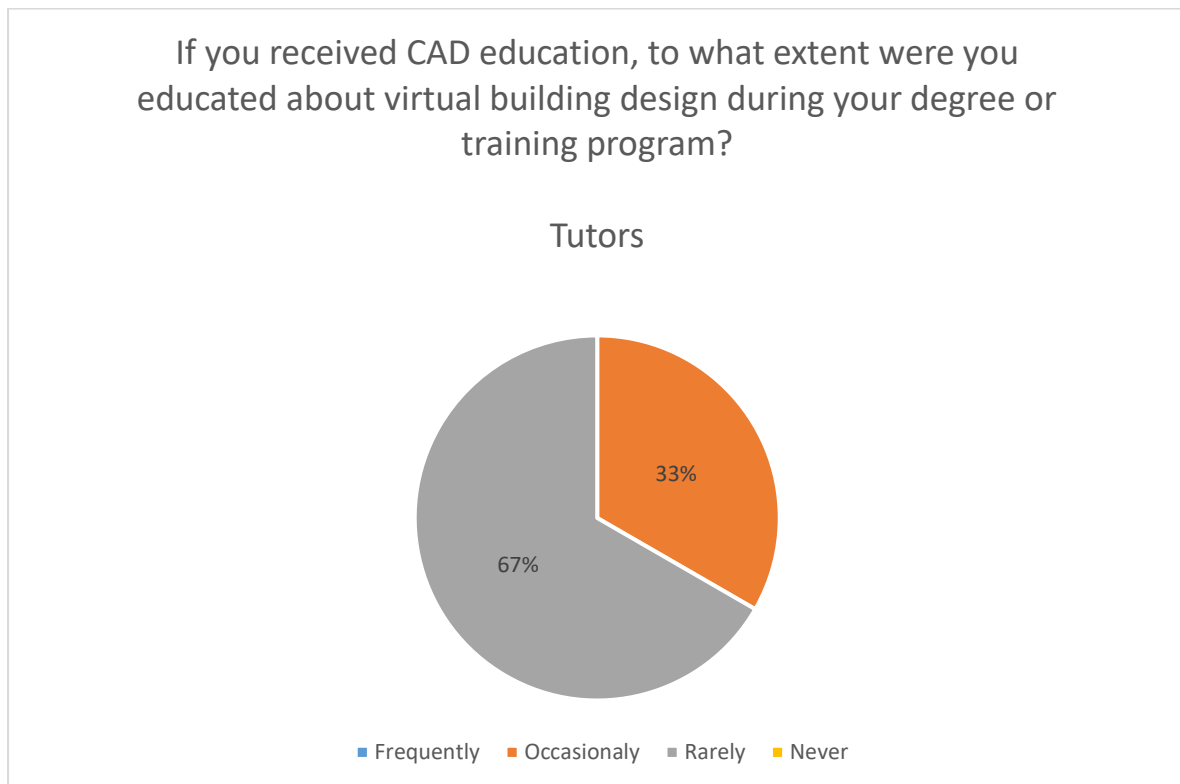
Figure 6.4.2.4 Presence of CAAD in Design Studios and Modules



Source: Compiled by the author, (2023)

Analysis: The established presence of CAAD in design studios indicates a readiness to enhance these practices with AR technologies. The balance between 'some' and 'a lot' suggests significant incorporation of digital tools, which can be further enriched with AR experiences.

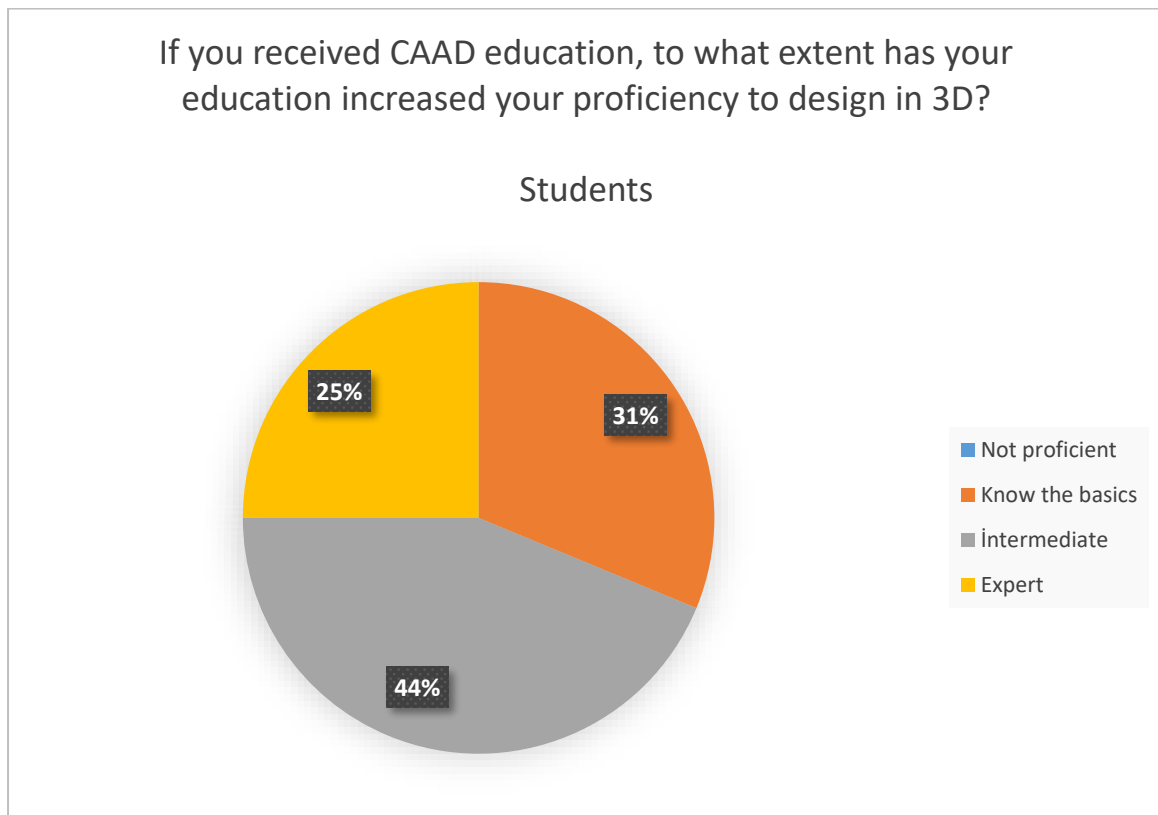
Figure 6.4.2.5 Education on Virtual Building Design (Tutors)



Source: Compiled by the author, (2023)

Analysis: This variation in VR education among tutors highlights the need for standardized training to ensure consistent competency in AR. Frequent to occasional exposure suggests a foundation upon which more immersive and comprehensive AR training can be built.

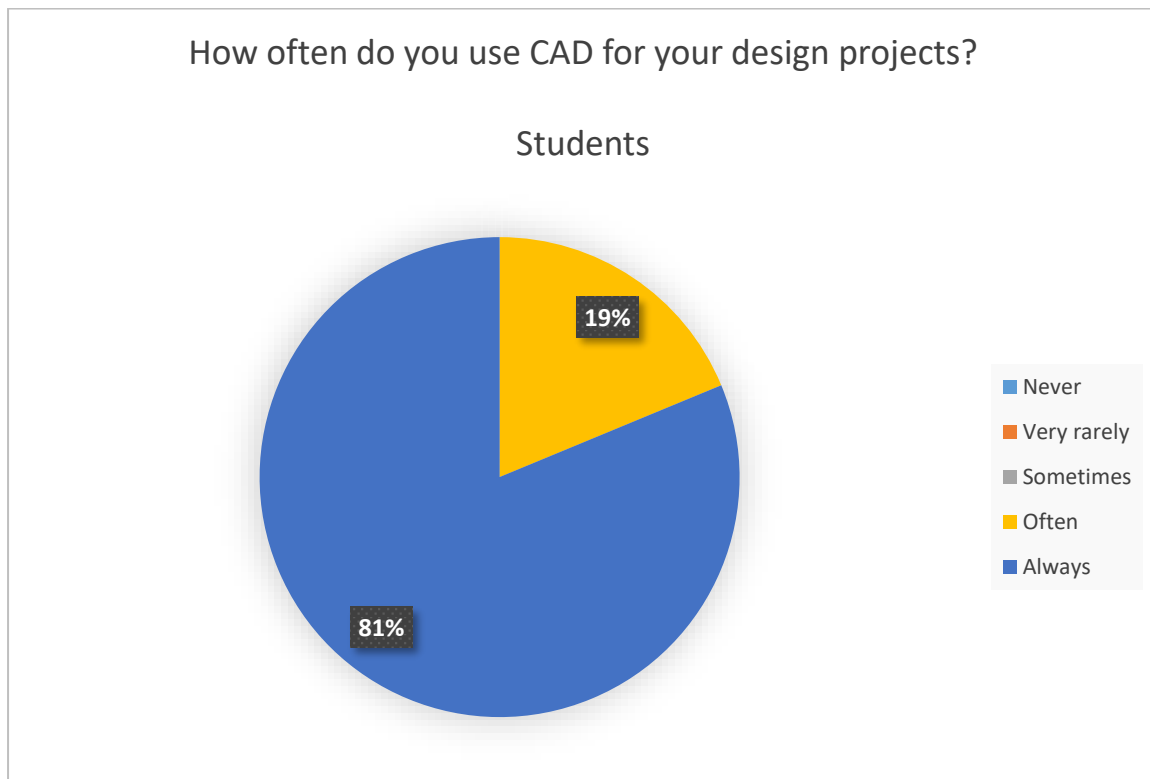
Figure 6.4.2.6 Proficiency in 3D Design Post-CAAD Education (Students)



Source: Compiled by the author, (2023)

Analysis: The high proficiency in 3D design among students indicates they are well-prepared to leverage AR for more advanced and immersive design projects. This proficiency suggests a strong potential for AR to further enhance their design capabilities.

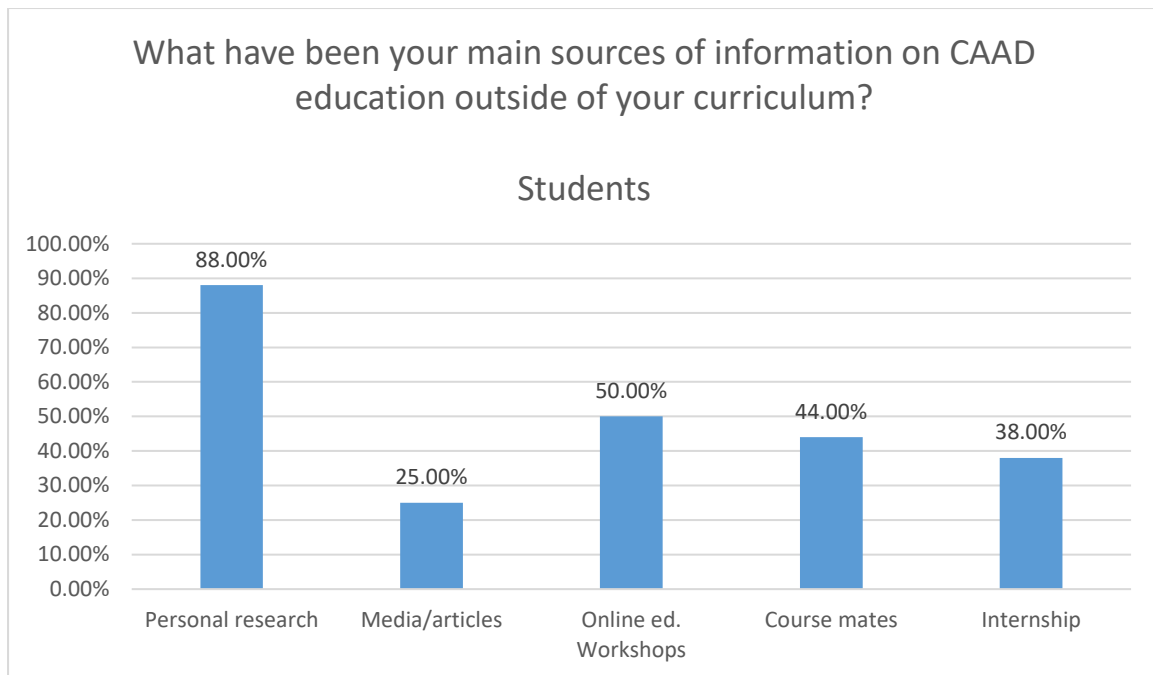
Figure 6.4.2.7 Frequency of CAD Use in Design Projects (Students)



Source: Compiled by the author, (2023)

Analysis: Regular use of CAD demonstrates the integral role of digital tools in students' design processes, paving the way for AR adoption. The frequent use underscores the importance of integrating AR to further enrich their design experience.

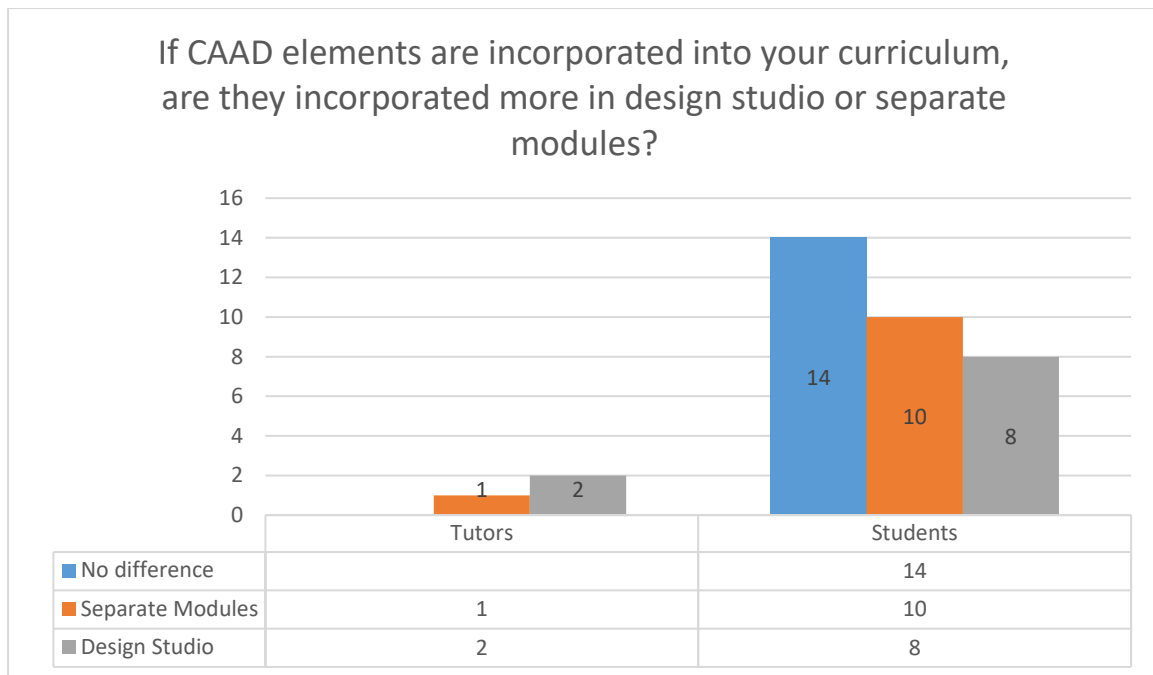
Figure 6.4.2.8 Main Sources of Information on CAAD Education (Students)



Source: Compiled by the author, (2023)

Analysis: The diverse sources of CAAD information highlight the proactive learning approaches of both students and tutors, which can be beneficial in integrating AR education. Personal research and peer collaboration are significant, suggesting a strong culture of self-directed learning.

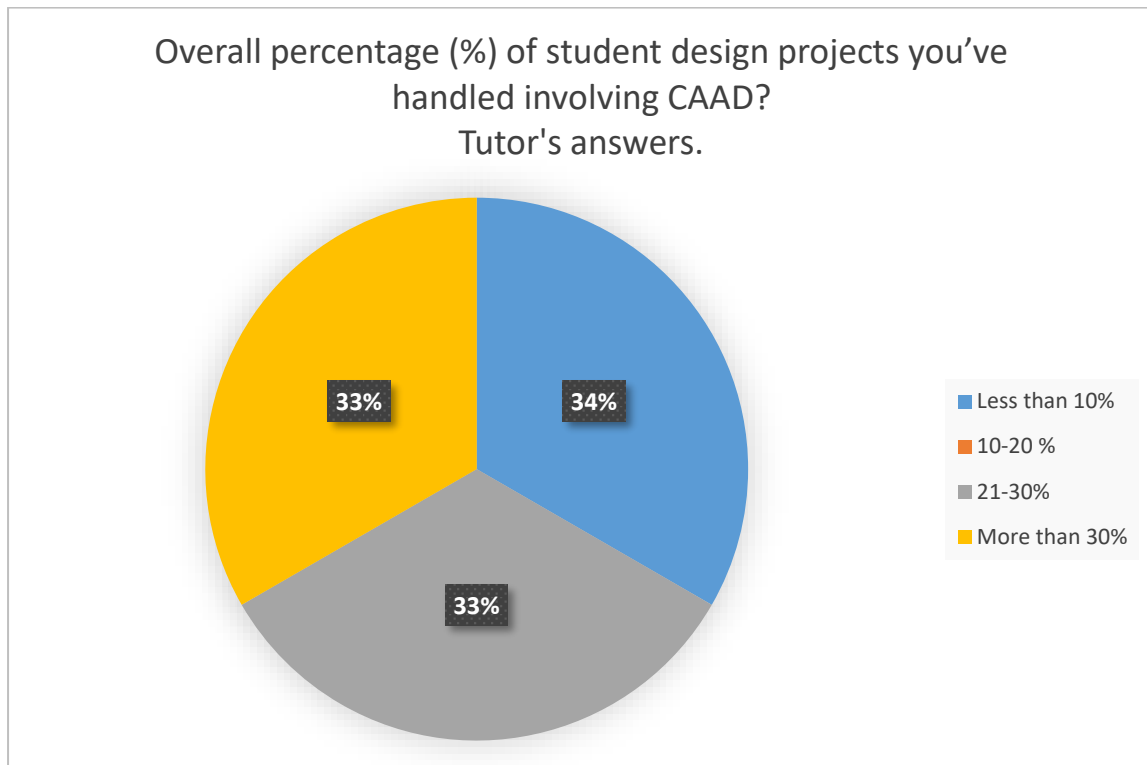
Figure 6.4.2.9 Integration of CAAD in Curriculum



Source: Compiled by the author, (2023)

Analysis: Flexible integration of CAAD indicates that AR can be similarly incorporated across different aspects of the curriculum to enhance learning. The varied responses suggest that both design studio and separate modules can effectively support digital tool integration.

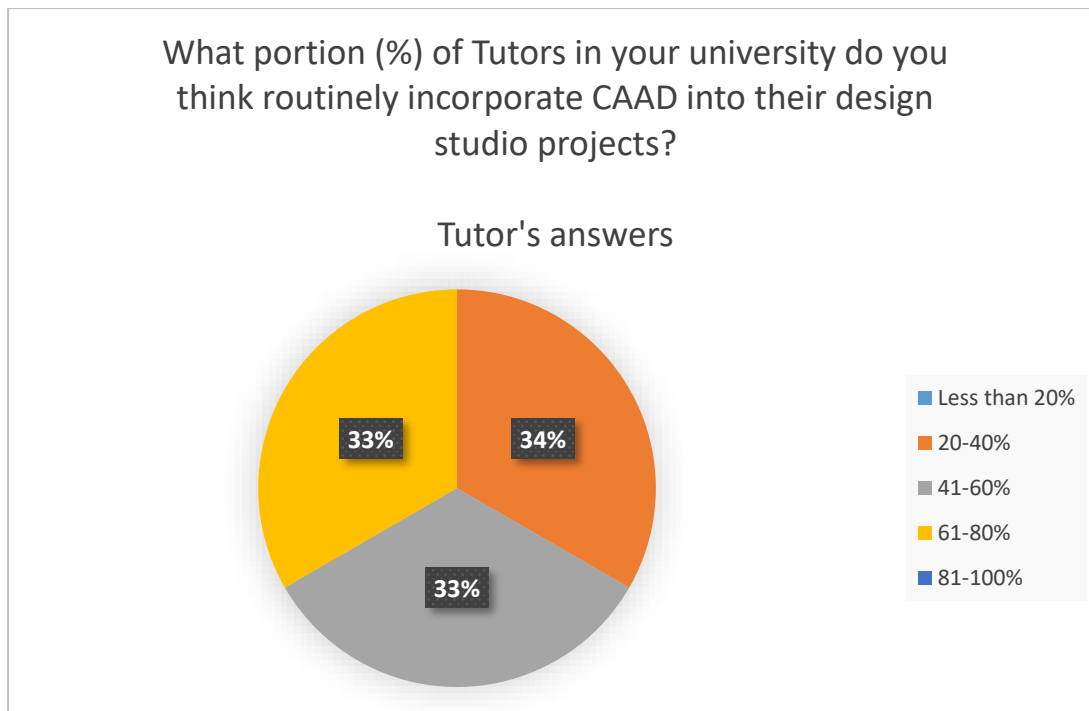
Figure 6.4.2.10 Percentage of Design Projects Involving CAAD (Tutors)



Source: Compiled by the author, (2023)

Analysis: The substantial integration of CAAD in design projects underscores the readiness for further incorporating AR technologies to enhance these projects. The balanced distribution indicates varying levels of CAAD engagement, all of which can benefit from AR integration.

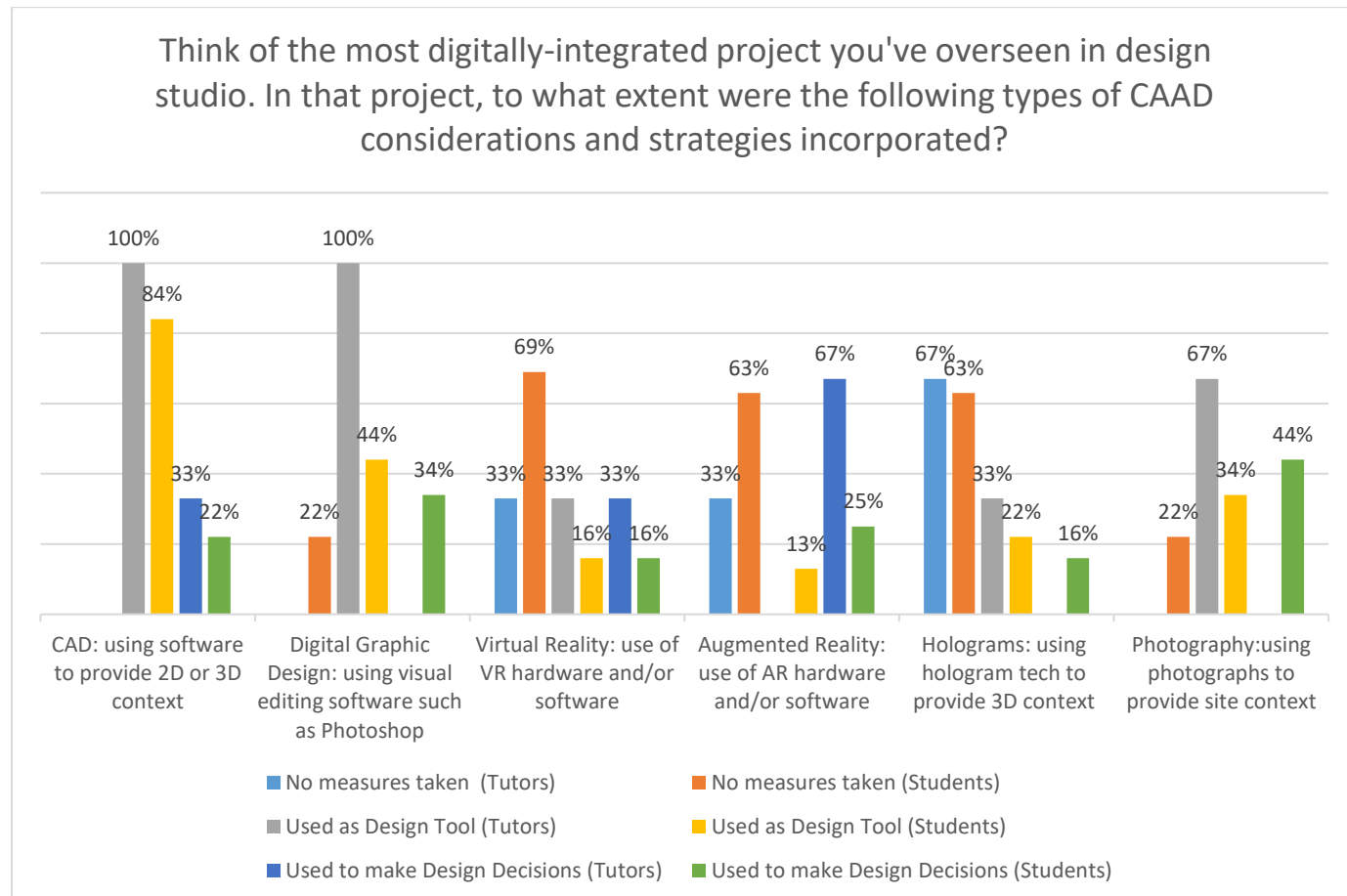
Figure 6.4.2.11 Routine Incorporation of CAAD by Tutors



Source: Compiled by the author, (2023)

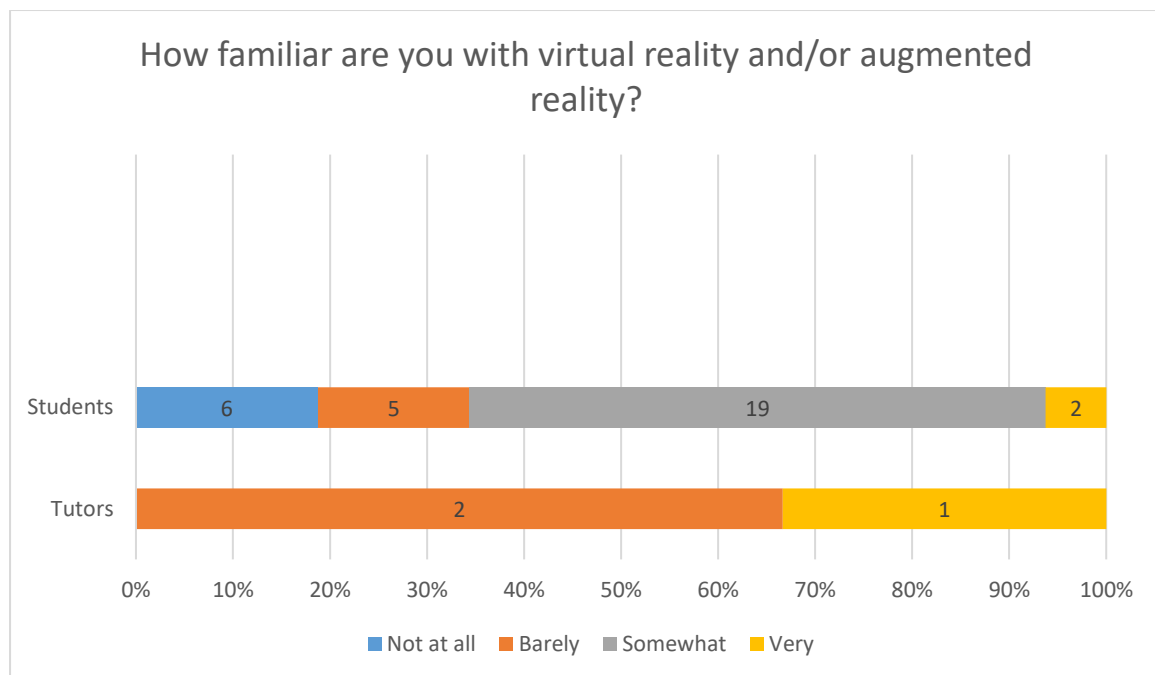
Analysis: This variation suggests opportunities for increased adoption and standardization of CAAD and AR practices among tutors. The presence of tutors at all levels of incorporation highlights the potential for broader engagement with AR technologies.

Figure 6.4.2.12 Level of incorporation of VR into various types of CAAD considerations and strategies



Source: Compiled by the author, (2023)

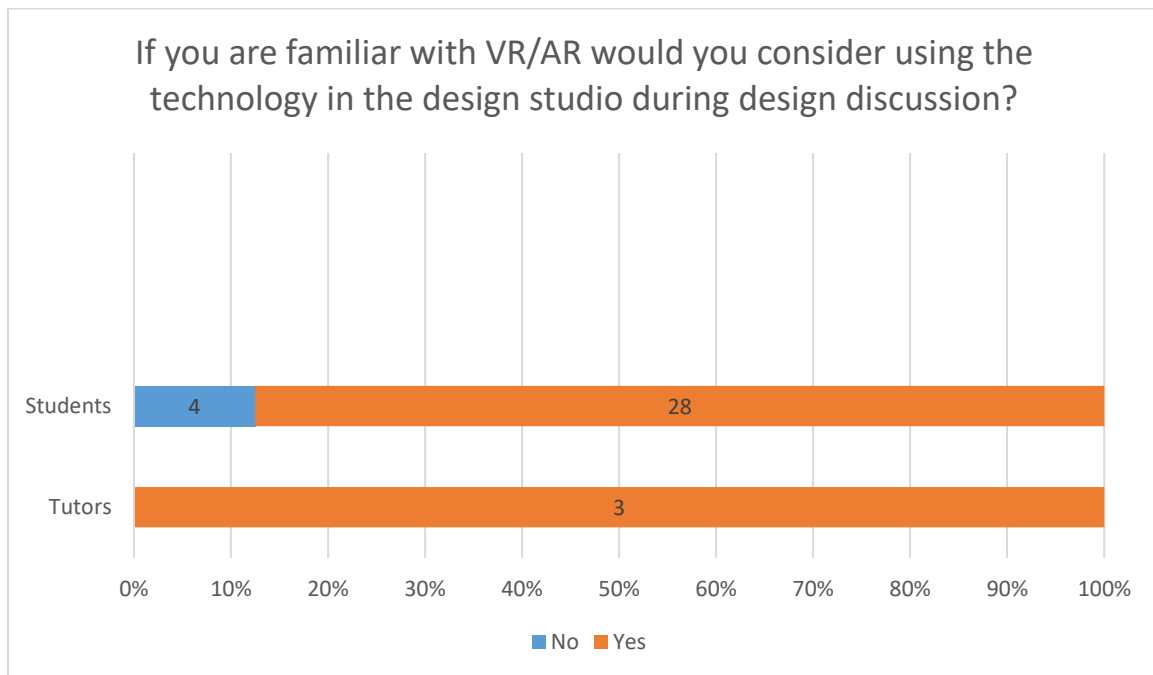
Figure 6.4.2.13 Familiarity with VR/AR



Source: Compiled by the author, (2023)

Analysis: General familiarity with VR/AR indicates a baseline knowledge that can be built upon with more immersive and hands-on experiences in the workshops. The higher familiarity among students suggests a readiness to explore VR/AR further. Although both students and tutors demonstrated varying levels of familiarity with VR/AR, students showed a slightly higher proportion in the “Somewhat familiar” and “Very familiar” categories. This may suggest a modest level of readiness among students, though it also indicates the need for consistent foundational training for all participants.

Figure 6.4.2.14 Willingness to Use VR/AR in Design Studios



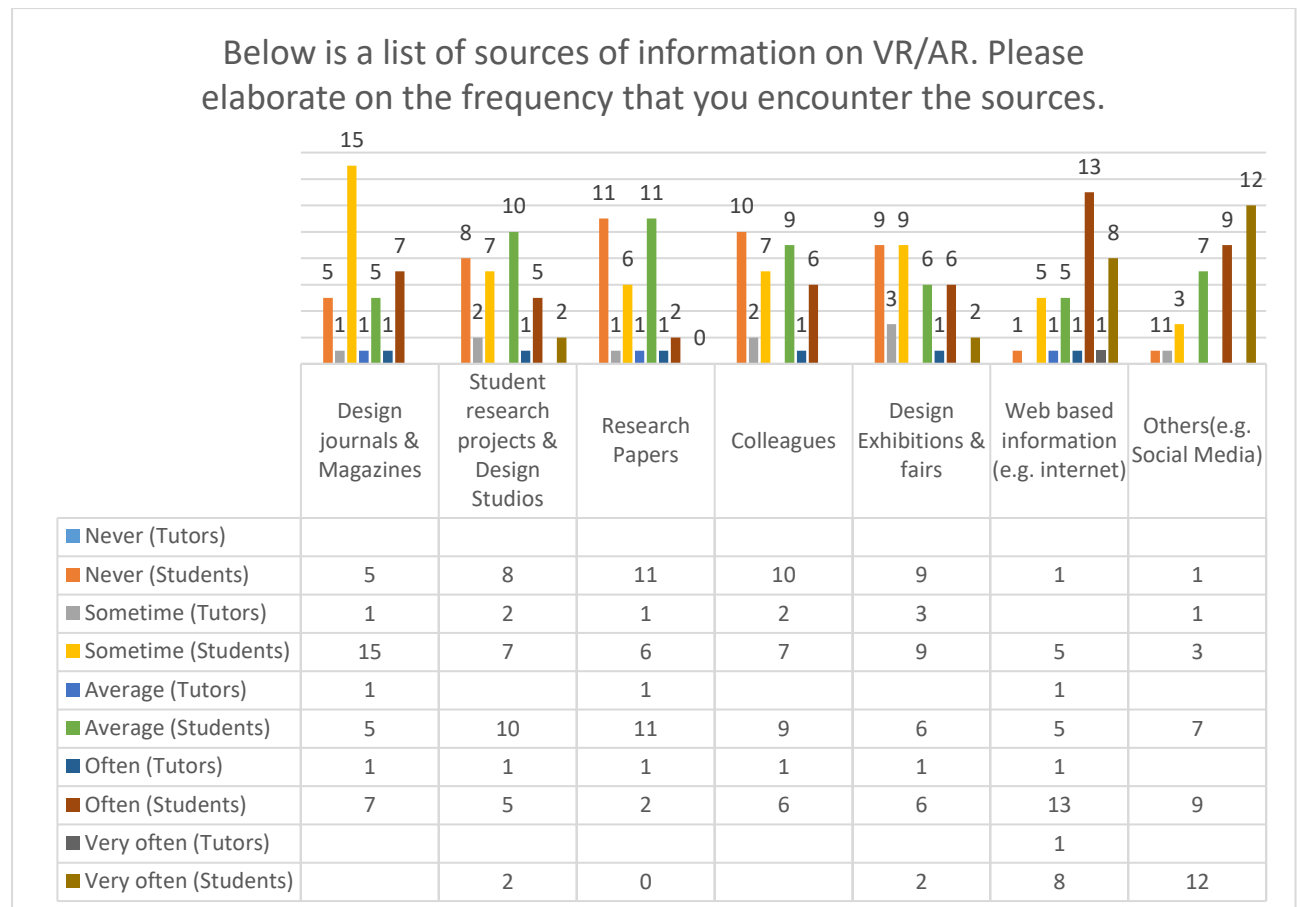
Source: Compiled by the author, (2023)

Analysis: The results show that among participants who are already familiar with VR/AR, there is a high willingness to adopt these technologies in the design studio: 87.5% of students and 100% of tutors indicated they would consider using them during design discussions.

This strong endorsement among familiar users suggests that once technological barriers and training are addressed, both students and tutors are likely to embrace immersive tools in design education.

However, since the question was limited to participants already familiar with VR/AR, these results cannot be used to infer overall willingness or openness across the entire population. Additional data would be needed to confirm broader attitudes toward adoption

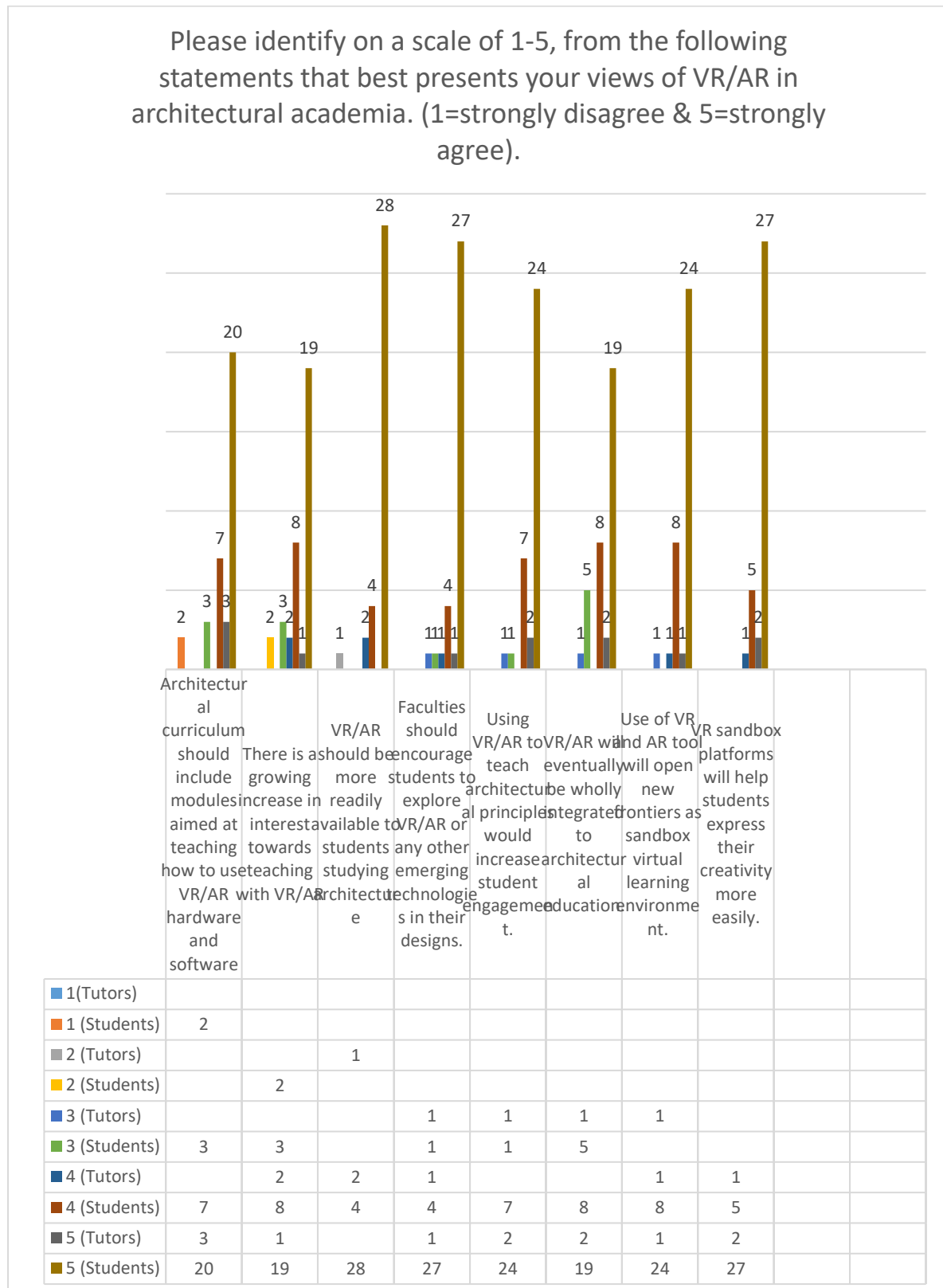
Figure 6.4.2.15 Sources of Information on VR/AR



Source: Compiled by the author (2023)

Analysis: The diverse sources of VR/AR information reflect the varied channels through which participants stay updated on emerging technologies. Web-based information and social media are particularly prominent, suggesting that online platforms play a crucial role in disseminating VR/AR knowledge.

Figure 6.4.2.16 Views on VR/AR in Architectural Academia



Source: Compiled by the author (2023)

Analysis:

A comparison between the pre-experiment data (Figure 5.5.3.20) and the follow-up (Figure 6.4.2.17) reveals important shifts in the perceptions of both students and tutors regarding the integration of VR/AR into architectural education.

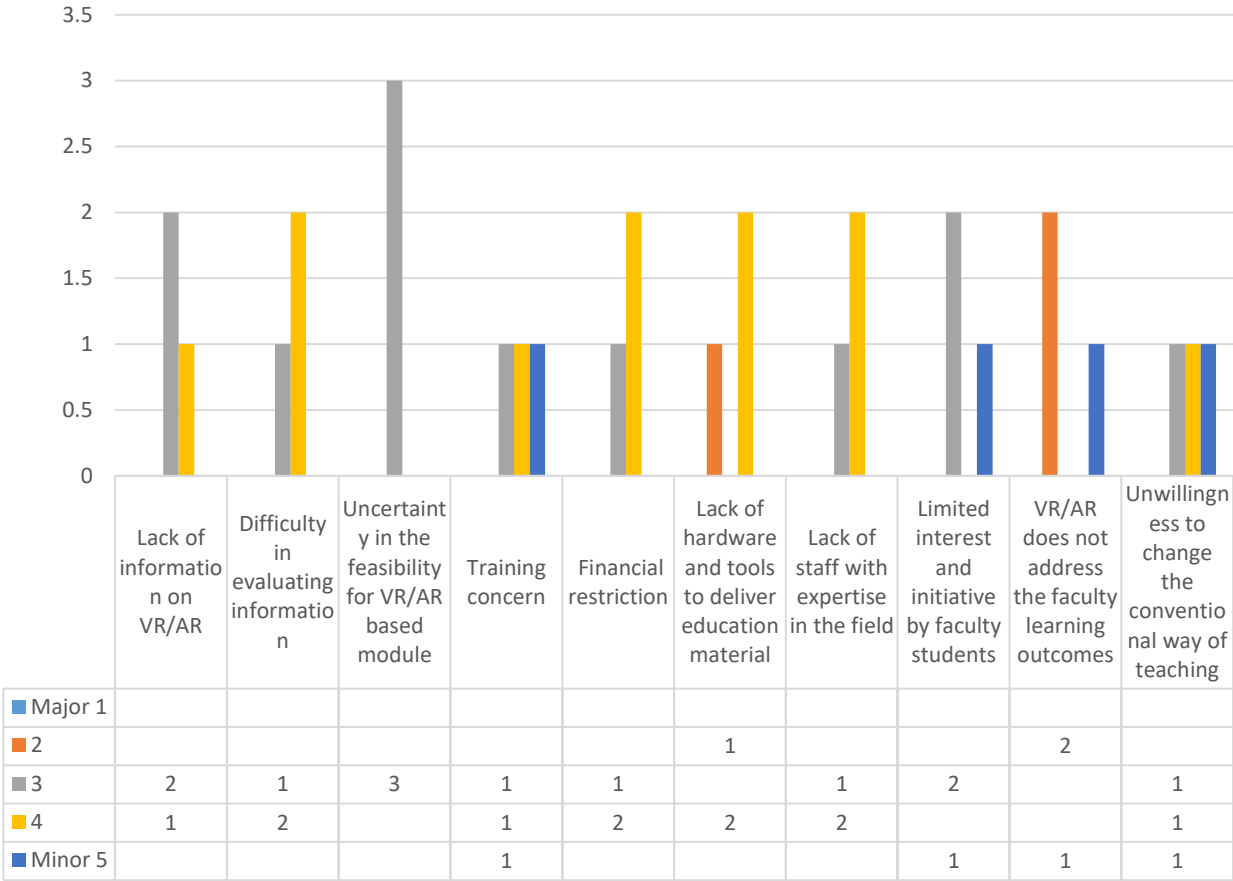
Specifically, in the earlier figure (5.5.3.20), students showed slightly higher agreement than tutors regarding the statement “Using VR/AR to teach architectural principles would increase student engagement” (58% vs. 50% strongly agree). Conversely, in Figure 6.4.2.17, tutors' strong agreement increased to 75%, surpassing students' 67%. This suggests that tutors became more optimistic about VR/AR's pedagogical impact, potentially influenced by workshop participation or exposure to technology during the study.

A similar trend appears in the statement “Architectural curriculum should include modules aimed at teaching how to use VR/AR hardware and software.” In Figure 5.5.3.20, 33% of tutors strongly agreed, whereas in Figure 6.4.2.17 this rose sharply to 100%. Among students, strong agreement increased modestly (46% to 63%). This indicates a significant shift in tutors' expectations, likely driven by an increased awareness of the importance of structured training in immersive technologies.

These contrasts suggest a growing alignment between tutors and students in recognising the pedagogical value of VR/AR. However, the variation in how each group prioritizes engagement versus curricular integration may also point to different short-term vs. long-term expectations. Students appear more immediately motivated by engagement, while tutors, following hands-on experience, begin to advocate for systematic curricular integration and formal training modules. This comparison also opens a pathway for further interpretation: it raises the possibility of investigating how expectations and perceived effectiveness of VR/AR differ between VR and AR specifically, especially since some statements may reflect the immersive (VR) or overlaid (AR) qualities differently. Future iterations of the study could consider disaggregating perceptions of VR and AR to better tailor training and curriculum design strategies.

Figure 6.4.2.18 Factors Hindering Integration of VR/AR Technologies (Tutors)

Figure 6.4.2.17 To what extent have the following factors hindered faculty from regularly integrating VR/AR technologies into their design projects?
Tutors answers.



Source: Compiled by the author (2023)

Participants rated the extent to which various factors hinder the integration of VR/AR technologies into design projects on a scale from 1 (minor) to 5 (major).

Analysis: The major factors hindering the integration of VR/AR technologies include lack of information, difficulty in evaluating information, financial restrictions, and lack of hardware and tools. Addressing these barriers through comprehensive training programs, financial support, and improved access to VR/AR resources is essential for successful integration and utilization of AR in design education.

Analysis: When comparing Figure 6.4.2.18 with Figure 5.5.3.21, a notable difference is observed in the distribution of responses across hindrance levels, particularly in the higher frequency of

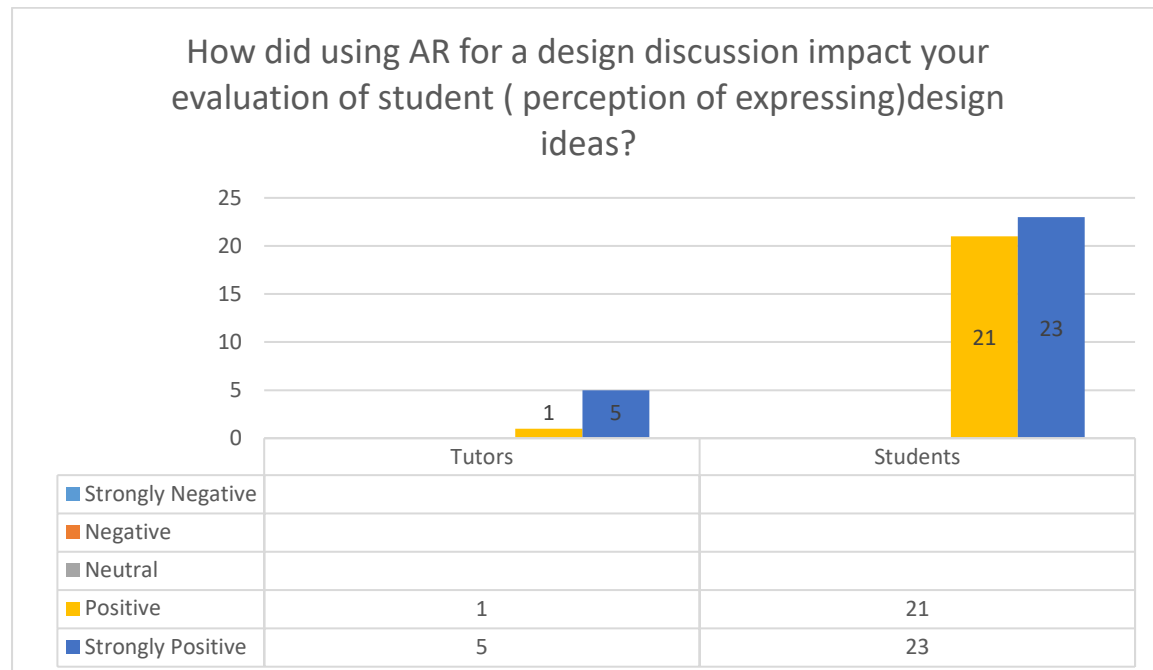
"Major 1" and "2" ratings for certain categories in Figure 5.5.3.21. This suggests that students perceive these barriers as more significant than tutors do. For example, while both groups acknowledge "lack of information on VR/AR" and "financial restriction" as critical barriers, students assign them greater weight. This distinction may reflect differing expectations or levels of reliance on institutional support between tutors and students.

Furthermore, this gap offers insights into how perceived feasibility and effectiveness of VR/AR integration differ between the two groups. Students might be more optimistic about its potential but feel more constrained by resource limitations, whereas tutors may see feasibility as more tied to curricular constraints and pedagogical readiness.

These differences emphasize the importance of designing tailored interventions that address both practical barriers (hardware, training, funding) and perceptual gaps (expectations, familiarity, pedagogical comfort). By triangulating these perceptions, educational institutions can more accurately align implementation strategies with the needs and concerns of both stakeholders.

6.5 Post experiment Results Analysis for AR (Augmented Reality) Workshop

Figure 6.5.1 The impact of AR on the perception of expressing design ideas



Source: Compiled by the author (2023)

Description: This graph illustrates the impact of AR on the perception of expressing design ideas during the workshops, as reported by students and tutors.

Analysis:

Students: Most students rated the impact as Strongly Positive, suggesting that AR significantly enhanced their ability to express design ideas. The ability to overlay digital designs onto physical spaces likely provided students with a more intuitive and practical understanding of their projects, making it easier to communicate their ideas.

Tutors: Tutors were similarly positive, indicating that they found AR beneficial in evaluating student design ideas. The interactive features of AR tools likely enabled tutors to provide more precise and actionable feedback, further enhancing the quality of design discussions.

Statistical Analysis:

Statistical testing confirmed that the use of Augmented Reality (AR) in design discussions significantly improved students' perception of their ability to express design ideas. Wilcoxon signed-rank tests revealed a highly significant improvement among students, with scores rising from a pre-intervention mean of 3.66 to 4.25 ($p < 0.001$). This substantial shift suggests that the spatial overlay and tangible context provided by AR enhanced students' design communication confidence, particularly as they became more comfortable with tools like Gravity Sketch and Shapr3D during the workshops.

Tutors also reported positive shifts, with their scores increasing from 3.80 to 4.51. However, this within-group change did not reach statistical significance ($p = 0.125$), likely due to a ceiling effect—tutors already entered the session with relatively high confidence in evaluating student design expression, limiting the extent of measurable improvement. This plateau is consistent with their prior experience and visual literacy, as discussed in earlier chapters.

Between-group comparisons showed no statistically significant difference post-intervention ($U = 25$, $p = 0.097$), despite the slight elevation in tutor scores (4.51) over student scores (4.25). This result suggests that AR's communicative benefits were experienced across the board, regardless of role or prior expertise.

The score distribution further supports this interpretation. Students showed a marked improvement after overcoming the initial technical barrier of interacting with AR interfaces. The combination of real-time edits, physical anchoring, and spatial scaling helped them better visualise and articulate complex design ideas. This reflects a broader pedagogical pattern noted in Chapter 4, where technological fluency mediates design clarity, especially for novice users. In contrast, tutors' stable high ratings underscore how AR served to reinforce and extend their existing evaluative capabilities.

These results closely mirror those from the earlier VR analysis (Figure 5.7.1), where immersive technology similarly enhanced students' ability to communicate their design intentions.

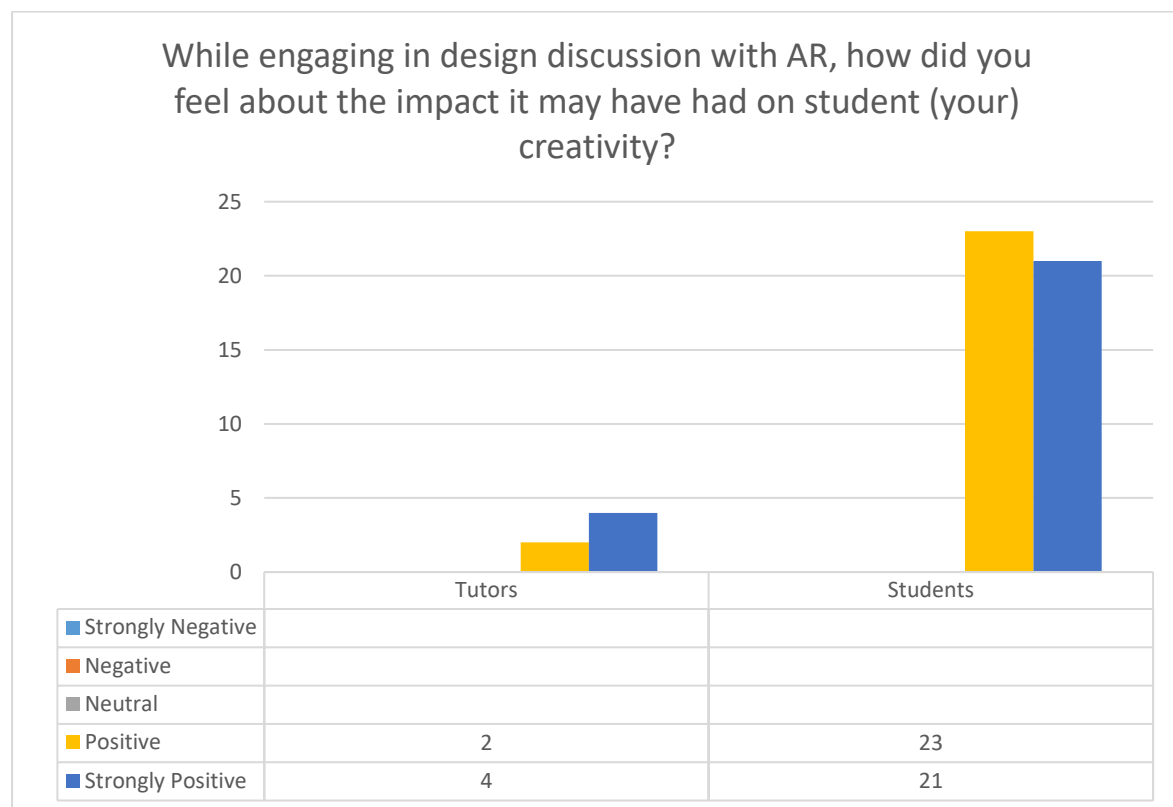
However, in the case of AR, the integration with the physical environment may have made spatial relationships and scale more intuitive—bridging the gap between conceptual intent and tangible output.

In summary, the AR intervention led to a statistically significant increase in students' confidence to express design ideas and maintained consistently high perceptions among tutors, further validating AR's value as a communicative design tool across different levels of expertise.



Image 6.5.1 Student exploring their early design idea in the University of Kyrenia (source: author, 2022)

Figure 6.5.2 The impact of AR on student creativity



Source: Compiled by the author (2023)

Description: This graph reflects the perceived impact of AR on student creativity during design discussions.

Analysis:

Students: A large number of students felt a Strongly Positive impact, indicating that AR facilitated creative expression during design discussions. The ability to visualize and manipulate designs in real-time likely encouraged students to experiment with new ideas and approaches, fostering creativity.

Tutors: Tutors also felt positive, suggesting that AR tools effectively supported creativity. This indicates that AR can enhance the teaching experience by providing a more dynamic and engaging platform for fostering creativity.

Statistical Analysis:

Statistical testing confirmed that the AR workshop had a strong, positive impact on students' perceptions of their creativity during design discussions. Wilcoxon signed-rank tests showed a highly significant increase from a pre-workshop mean of approximately 3.21 to a post-workshop mean of 4.09 ($p < 0.001$). This substantial gain ($\Delta \approx +0.88$) reflects the role of AR's spatial anchoring and real-time manipulation in enabling more speculative, exploratory thinking—features students referenced in both the post-questionnaire and informal discussions.

Tutors also reported an increase in creativity perception, from 3.80 to 4.18, though this within-group improvement did not reach statistical significance ($p = 0.188$). The smaller numerical change ($\Delta \approx +0.39$) and limited sample size ($n = 5$) likely contributed to the lack of statistical power. Additionally, tutors began from a relatively high baseline, suggesting a ceiling effect. Their qualitative comments highlighted appreciation for AR's ability to support variation and iteration, but also indicated they were already predisposed toward valuing open-ended design strategies.

A Mann–Whitney U test comparing post-workshop creativity scores between students and tutors showed no significant difference ($U = 40$, $p = 0.53$), with both groups converging around scores between 4.1 and 4.2. This convergence is particularly noteworthy as it suggests that AR helped bridge the gap in creative perception between novices and experts, offering a shared platform where both could engage meaningfully in ideation.

When comparing AR to the earlier VR results, no statistically significant differences emerged. Students' post-VR creativity score (≈ 4.05) was similar to their AR score (≈ 4.09 , $U = 180$, $p = 0.598$), while tutors' scores were also statistically indistinguishable across the two platforms (VR ≈ 4.30 vs AR ≈ 4.18 , $U = 17$, $p = 0.421$). This suggests that both VR and AR are equally effective in fostering creativity, albeit through different experiential routes: VR through full environmental immersion, and AR through embedded spatial context that connects design to real-world scale, site, and setting.

These results align with discussions in Chapter 3, particularly the emphasis on embodied cognition and situated design thinking (Malinin, 2016; Oxman, 2006), which position physical engagement with space as a driver of ideation. AR's ability to project digital forms into the real world allowed students to consider light, orientation, and materiality more intuitively, potentially unlocking new creative directions.

In summary, the AR workshop produced a statistically significant creative uplift for students, with tutors affirming this potential through consistently high post-ratings. The comparison with VR indicates that both modalities are robust enablers of design creativity, offering instructors and institutions the flexibility to tailor immersive technologies to the goals of specific modules or phases of design education.

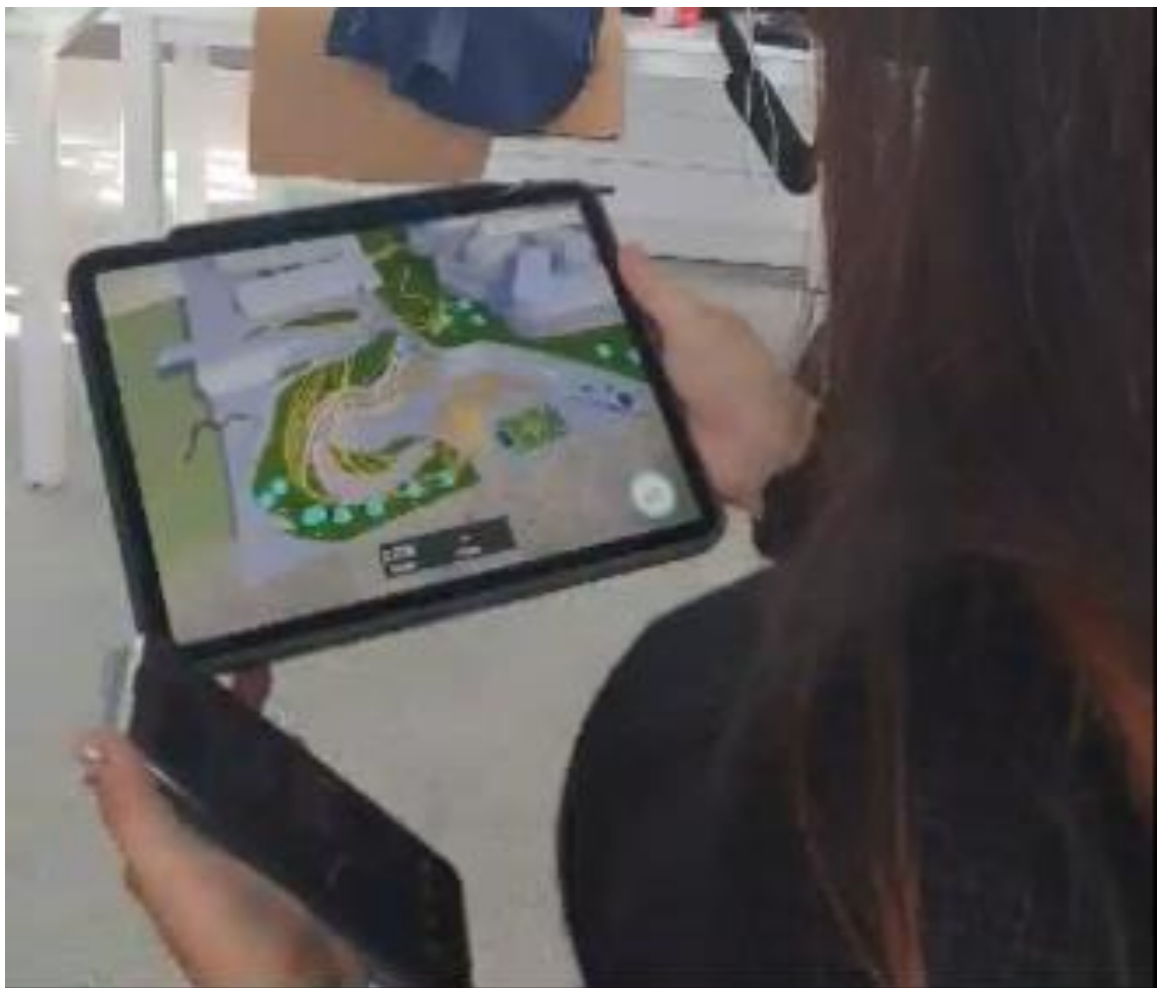
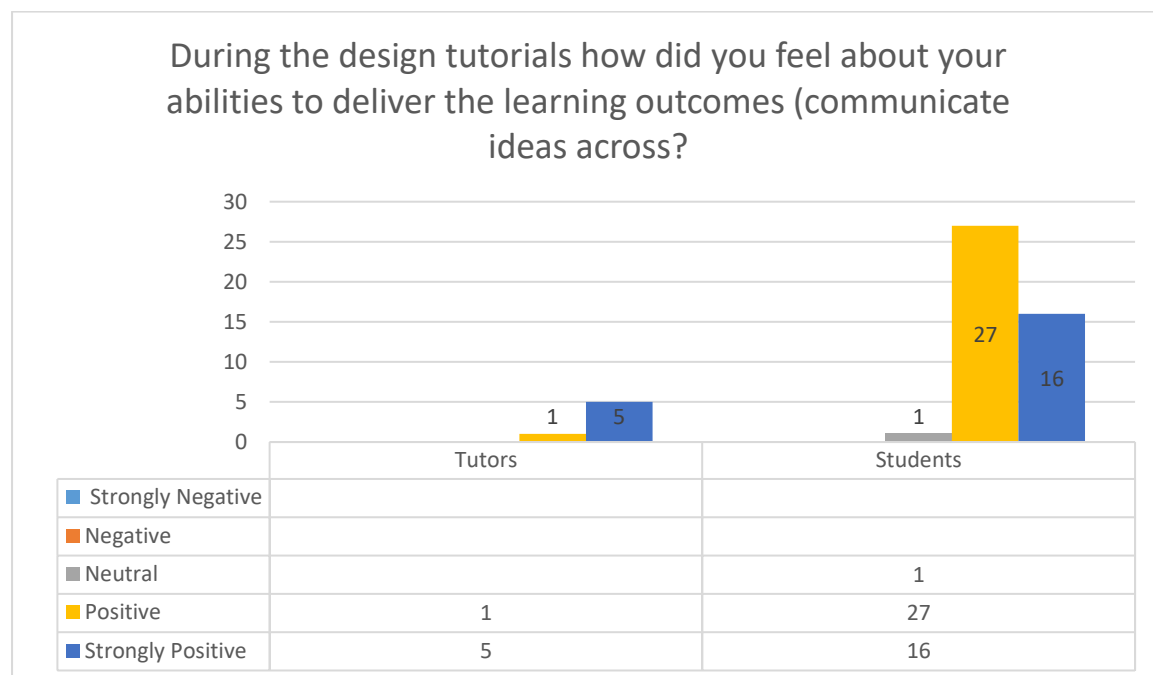


Image 6.5.2 Student sketching and experimenting on their design in Near East University (source: author, 2022)

Figure 6.5.3 AR's abilities to deliver the learning outcomes



Source: Compiled by the author, (2023)

Description: This graph evaluates the confidence of students and tutors in their ability to communicate ideas using AR during design tutorials.

Analysis:

Students: The majority of students felt Strongly Positive about their ability to communicate ideas, indicating that AR enhanced their confidence in delivering learning outcomes. The intuitive nature of AR likely made it easier for students to convey complex design concepts, improving their overall communication skills.

Tutors: Tutors felt confident as well, but some indicated a need for further adaptation to AR tools for effective communication. This highlights the importance of continuous training and support to ensure both students and tutors can fully leverage the benefits of AR.

Statistical Analysis:

Statistical testing revealed that AR had a positive effect on students' confidence in delivering learning outcomes during the design tutorials, with their mean scores increasing significantly from 3.42 to 3.88 ($p = 0.012$, Wilcoxon $V = 39$). This gain reflects how AR's spatial anchoring, gesture-based manipulation, and context-sensitive overlays supported clearer articulation of design concepts. Students frequently reported that projecting models onto real environments helped them "see" and explain relationships more easily, particularly in group discussions or tutorial critiques.

Tutors also showed an increase in communication confidence, from 3.75 to 4.32, but this change did not reach statistical significance ($p = 0.188$, $V = 2$). This is likely due to a combination of high pre-workshop confidence levels and small sample size, both of which constrain the potential for measurable gain. Nevertheless, tutors maintained high post-workshop scores, confirming that AR was perceived as an effective tool for guiding discussions and delivering feedback.

A Mann–Whitney U test comparing student and tutor post-scores revealed a significant difference between the groups ($U = 20$, $p = 0.042$), with tutors expressing greater overall confidence (mean ≈ 4.32) than students (mean ≈ 3.88). This finding suggests that while both groups benefitted, tutors were better able to exploit AR's communicative affordances—possibly due to their spatial fluency, confidence in critique, and adaptability in managing multi-modal tools.

When comparing AR to VR, a clear distinction emerges in how students responded to each platform. Students' post-VR communication confidence (mean ≈ 4.20) was significantly higher than their post-AR score (mean ≈ 3.88), with $U = 328$ and $p = 0.001$. This suggests that VR—offering immersive control, smoother navigation, and

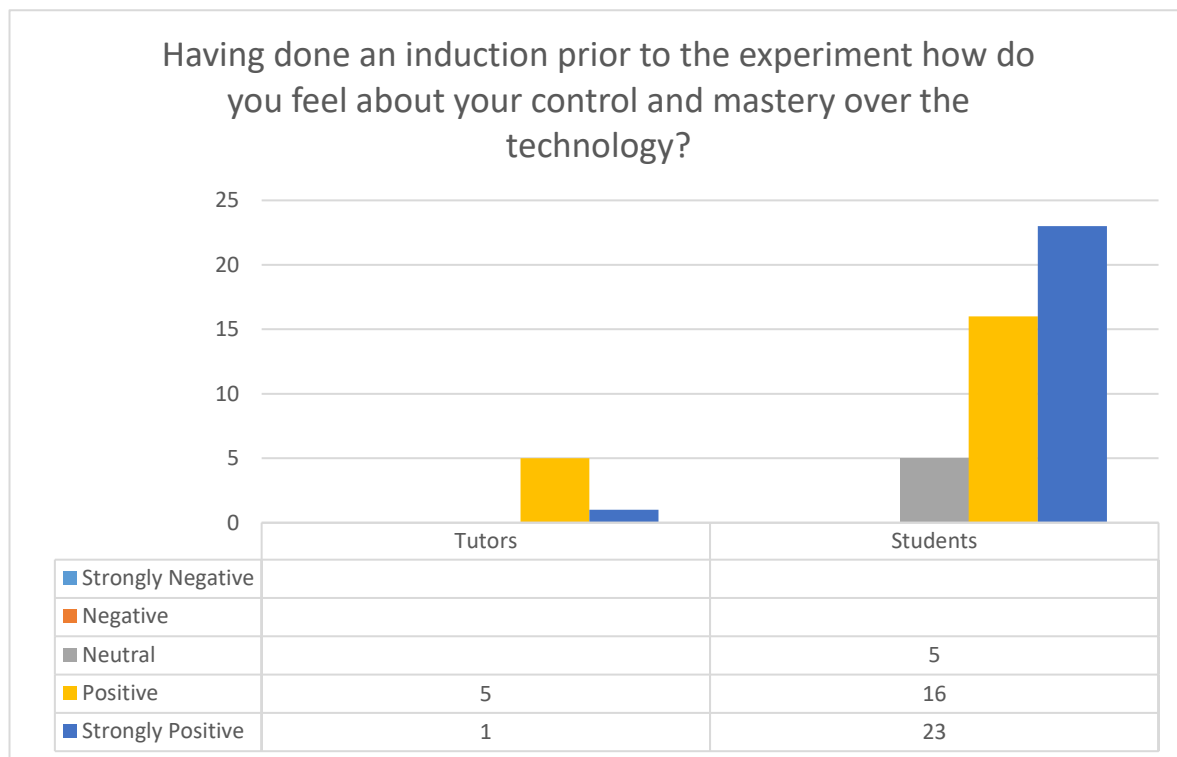
uninterrupted visual feedback—provided a more supportive environment for students to develop and express design ideas. Tutors, by contrast, showed no significant difference between VR (mean ≈ 4.60) and AR (mean ≈ 4.32), indicating that either platform sufficiently met their communication needs ($U = 18, p = 0.31$).

The distribution of scores reinforces this interpretation. Students' communication confidence increased with AR, but the broader spread and modest mean suggest a slight hesitation or friction in adapting to mixed-reality interfaces. In contrast, VR's fully immersive setup likely offered a more focused and stable setting for novice communicators. Tutors, already operating from a position of comfort in critique, demonstrated uniformly high post-scores across both technologies—validating both as reliable channels for delivering learning outcomes.

These findings support a blended pedagogical approach. As discussed in Chapter 4, immersive technologies should not be framed as interchangeable but as complementary tools: VR may be best deployed early to establish spatial confidence and build communication fluency, while AR can later reinforce these skills through contextual engagement and real-world overlays.

In summary, AR significantly improved students' confidence in delivering learning outcomes, though VR outperformed AR for students in this category. Tutors rated both platforms highly, suggesting AR and VR can be strategically sequenced to scaffold communication skills throughout the design education process.

Figure 6.5.4 Control and mastery over the AR technology



Source: Compiled by the author (2023)

Description: This graph assesses the proficiency levels of students and tutors in using AR technology after an induction session.

Analysis:

Students: A majority of students rated their proficiency as Strongly Positive, indicating that the induction sessions were effective in preparing users to utilize the AR tools competently. This suggests that with adequate training, students can quickly become proficient in using AR, which is essential for integrating this technology into the curriculum.

Tutors: Tutors also felt proficient, but some indicated a need for ongoing support and practice. This underscores the importance of continuous professional development to ensure tutors remain adept at using new technologies in their teaching practices.

Statistical Analysis

Statistical testing confirmed that the induction session had a highly significant impact on students' perceived control and mastery over AR tools. Students' mean scores increased from 3.02 to 3.91, with the Wilcoxon signed-rank test confirming this gain as statistically significant ($p < 0.001$, $V = 16$). This sharp improvement highlights the effectiveness of the structured onboarding process, which enabled novices to transition from initial hesitation to confident, functional use of AR platforms like Shapr3D and Gravity Sketch on tablets.

Tutors also experienced a notable gain in proficiency—from a pre-workshop mean of 3.19 to 4.15—but this increase did not reach conventional statistical significance ($p = 0.062$, $V = 0$). However, the magnitude of the gain ($\Delta \approx +0.96$) still indicates meaningful improvement. The lack of significance is likely due to the small sample size ($n = 5$) and higher starting baseline, reflecting a ceiling effect among tutors who already possessed foundational competence in digital design tools.

When comparing post-workshop mastery between the two groups, the Mann–Whitney U test yielded no significant difference ($U = 27$, $p = 0.129$), suggesting that both students and tutors achieved comparable levels of operational fluency with AR by the end of the workshop. This convergence is a strong endorsement of the induction format, which succeeded in closing the initial experience gap between novices and experts.

Cross-platform comparisons revealed no significant differences in perceived control between AR and VR. For students, the post-VR score (≈ 4.00) was statistically indistinguishable from the AR post-score (≈ 3.91), with $U = 223$ and $p = 0.543$. Similarly, tutors showed no difference in perceived mastery across platforms (VR ≈ 4.40 vs AR ≈ 4.15 , $U = 14$, $p = 0.841$). These results

suggest that once a solid induction is in place, platform-specific interfaces—though technically distinct—do not meaningfully affect users’ confidence or operational ability.

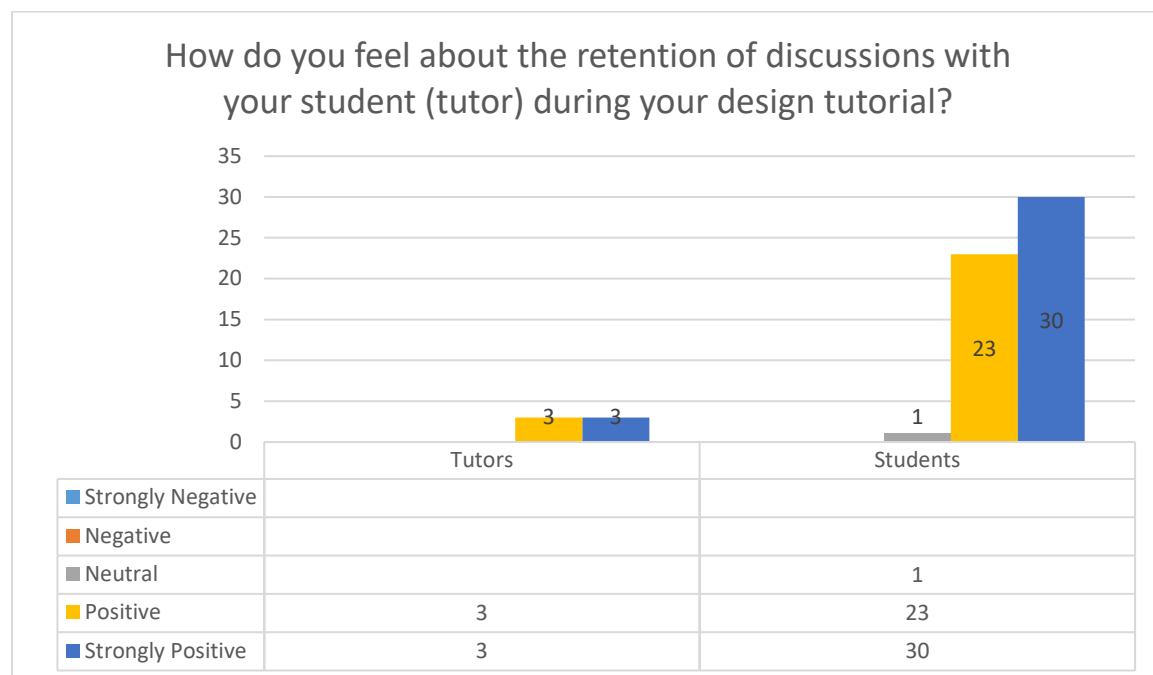
The broader implications support themes introduced in Chapter 4: early-stage training and familiarisation are critical in immersive learning contexts. Students demonstrated a strong ability to adapt and perform once scaffolded, while tutors benefitted from reinforcement and exposure to new interface subtleties. Importantly, the shared control patterns between AR and VR (e.g., gesture navigation, 3D manipulation, scaling) allow for skill transfer between platforms—supporting modular and flexible integration of immersive tools within the curriculum.

In summary, AR induction significantly elevated students' mastery levels to nearly match those of tutors, and both groups ended with high confidence across AR and VR. These findings reinforce the value of structured training and confirm that immersive technology fluency is attainable for all users, regardless of prior experience, when guided by well-designed pedagogical support.



Image 6.5.3 Student exploring and trying different tools with AR in the University of Kyrenia (source: author, 2022)

Figure 6.5.5 Impact of AR on student retention of discussion



Source: Compiled by the author (2023)

Description: This graph evaluates the retention of information from AR design tutorials as reported by students and tutors.

Analysis:

Students: Most students reported Strongly Positive retention, suggesting that AR facilitated better retention of design discussions. The immersive and interactive nature of AR likely contributed to this by making the learning experience more engaging and memorable.

Tutors: Tutors also reported good retention, indicating that AR supports effective learning and memory. This suggests that AR can enhance the overall quality of education by improving information retention and recall.

Statistical Analysis:

Statistical testing confirms that the AR workshop led to a substantial and significant improvement in students' retention of tutorial content. Students' mean scores rose from approximately 3.15 pre-workshop to 3.90 post-workshop, with a Wilcoxon signed-rank test revealing a highly significant result ($p < 0.001$, $V = 11$). This suggests that AR's context-rich overlays—linking digital objects directly to the physical studio or site environment—enhanced memory encoding by activating dual-coding mechanisms (Paivio, 1986) and embodied cognition pathways, both of which are discussed in Chapter 3 of your literature review.

Tutors also experienced a meaningful gain, with mean retention scores increasing from 3.64 to 4.43. Though this change narrowly missed statistical significance ($p = 0.062$, $V = 0$), the effect size ($\Delta \approx +0.79$) remains substantial. The lack of statistical power is likely attributable to the small sample size ($n = 5$). Nevertheless, qualitative comments from tutors aligned with this numerical gain—they noted greater clarity and continuity in conversations when interacting with student work in context, echoing Dourish's (2001) arguments around situated action and embodied interaction in technology-enhanced collaboration.

A Mann–Whitney U test comparing post-AR scores between students and tutors showed a significant difference ($U = 19$, $p = 0.035$), with tutors reporting higher retention. This is consistent with the novice–expert gap referenced in your literature review: experts are more adept at organising and integrating new information into existing cognitive schemas (see Lawson, 2005; Schön, 1983), giving them an edge in synthesising and retaining tutorial discussions—even when presented through new media like AR.

When placed in conversation with VR findings, no statistically significant difference was observed in retention between the platforms for students ($U = 258$, $p = 0.12$), though VR showed a modest numerical advantage (VR mean ≈ 4.10 vs AR ≈ 3.90). This suggests that while AR offers contextually grounded learning, VR may create immersive isolation that reduces distraction and

enables deeper focus—mirroring findings from Chapter 4 where VR was seen as enhancing attentional control and continuity of spatial narrative (Milovanovic et al., 2017).

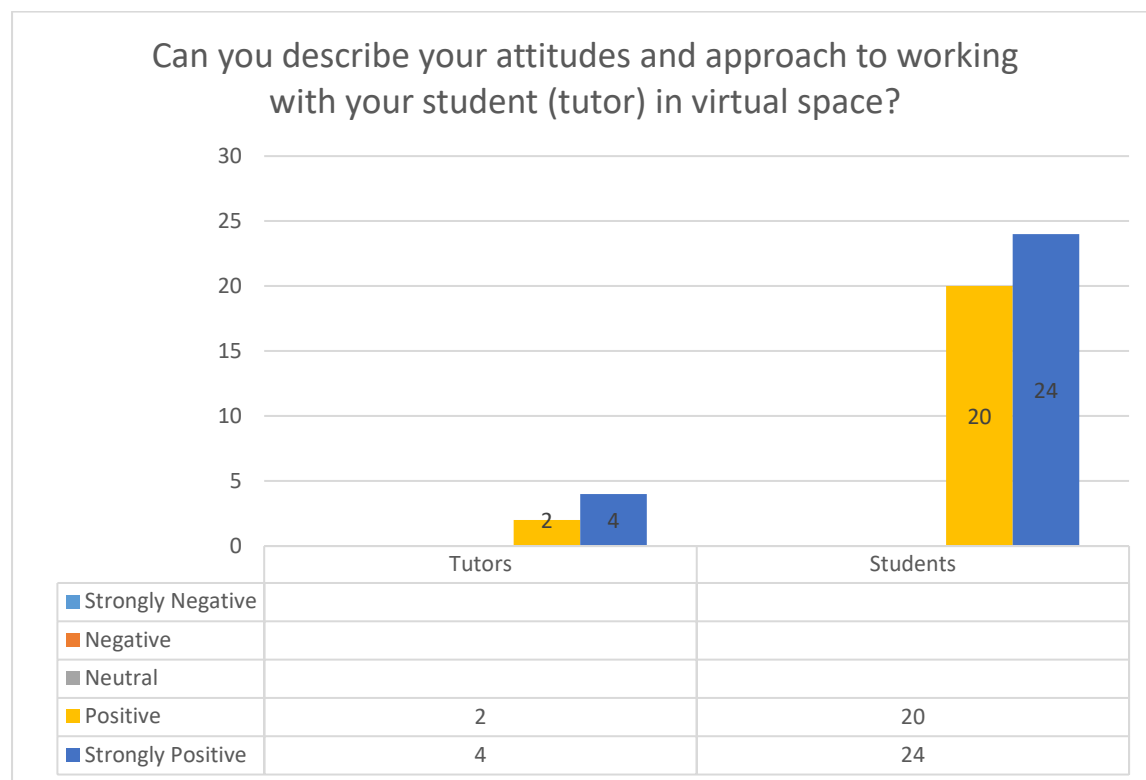
For tutors, no difference emerged between AR and VR ($U = 13$, $p = 1.00$), with both post-scores clustering tightly around 4.4. This parity supports the notion that experts benefit consistently from any immersive platform that allows for embodied interaction and design engagement.

Key influencing factors include:

- Contextual Anchoring (AR): Students benefitted from seeing design feedback materialise in the same environment where they work and reflect. This echoes Schnabel's (2009) emphasis on co-located digital/physical design learning.
- Cognitive Scaffolding (VR): VR's immersive focus may aid in reducing extraneous cognitive load, particularly beneficial for novices still building spatial and verbal fluency.
- Expertise Modulation: Tutors leverage meta-cognitive skills to navigate either platform effectively, suggesting that future curriculum design should scaffold students' transition from reactive use to strategic deployment of immersive tools, as discussed in your pedagogical framework (Chapter 4).

In summary, AR significantly improves retention of design discussions, particularly for students, by embedding feedback into lived, visual-spatial contexts. While VR shows a slight retention edge for students, both tools yield comparable, high-level gains for tutors, supporting their integration as complementary approaches in studio-based architectural education.

Figure 6.5.6 Student's attitude and approach to working in virtual space



Source: Compiled by the author, (2023)

Description: This graph highlights impact of AR on design collaboration for student and tutor groups

Statistical Analysis:

The AR workshop led to a significant shift in participants' attitudes toward virtual collaboration, with both students and tutors reporting overwhelmingly Positive or Strongly Positive experiences following the session. Students showed a dramatic and statistically significant improvement in attitude, with mean scores increasing from approximately 3.30 to 4.55 ($p < 0.001$, Wilcoxon $V = 0$). This jump reflects not only growing confidence in using AR tools, but also a recognition of their value in supporting group work and peer interaction in spatial design contexts.

Tutors also reported a significant attitudinal gain, with scores rising from 3.50 to 4.67 ($p = 0.038$, Wilcoxon $V = 0$). Although tutors entered the workshop with more open perspectives, the

opportunity to experience AR in a real teaching context deepened their appreciation for its collaborative affordances—particularly the ability to share, scale, and annotate designs in real time, with students physically co-located or interacting asynchronously via shared devices.

The Mann–Whitney U test comparing post-workshop attitudes between students and tutors showed no statistically significant difference ($U = 116, p = 0.591$), indicating

cating that AR helped bring both groups to a similarly high level of enthusiasm for virtual design collaboration. This convergence is especially meaningful, as it suggests that AR played a levelling role—bridging experience gaps and making immersive digital collaboration equally accessible to novices and experts.

This finding resonates strongly with themes from your literature review—particularly the notion of collaborative presence and shared virtual space as central to meaningful learning (Milovanovic et al., 2017; Dourish, 2001). The spatialized, real-time interaction facilitated by AR mirrors traditional design studio dynamics, but with the added benefit of digital enhancement. As argued by Oxman (2006), such environments foster "distributed cognition," allowing learners to externalize and iterate upon ideas more fluently through augmented shared representations.

Several factors likely contributed to this positive outcome:

- Demystification through induction: Hands-on training helped eliminate apprehension toward using AR for teamwork, especially among students. This aligns with your earlier findings that structured onboarding significantly improves self-efficacy with immersive technologies.
- Engagement through novelty and functionality: For students, the leap in attitude reflects not just excitement about new tools, but their recognition of how AR can practically support peer critique, iterative development, and spatial dialogue—hallmarks of effective studio pedagogy.

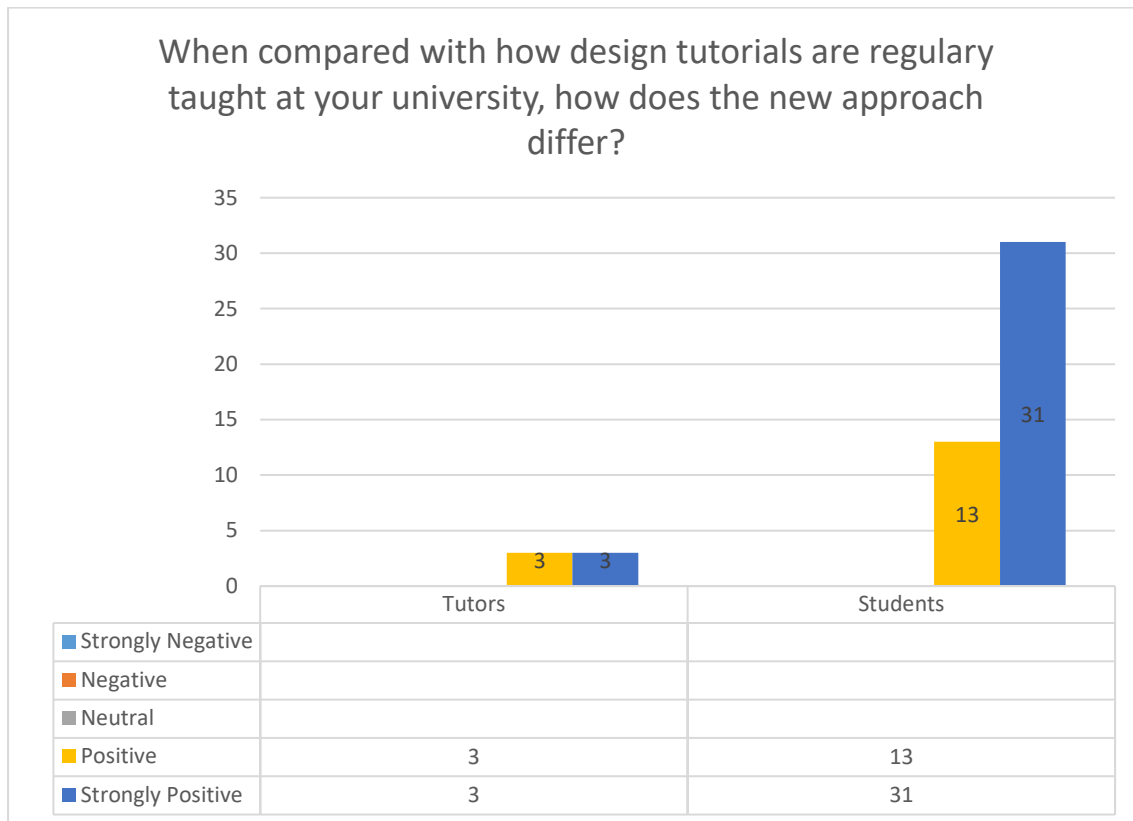
- Pedagogical value for tutors: For tutors, the workshop provided an opportunity to observe AR's potential to facilitate dialogic learning, echoing Schön's reflective practitioner model (1983), where the design conversation becomes the medium of learning.

In summary, AR significantly enhanced both student and tutor attitudes toward virtual collaboration, producing convergent positivity across roles and experience levels. This result reinforces AR's value not just as a representational tool, but as a social and cognitive scaffold for collaborative learning in architectural design education. Integrating AR into group-based studio activities could therefore promote deeper engagement, peer feedback, and mutual spatial understanding—key elements identified in your pedagogical framework in Chapter 4.



Image 6.5.4 Student and Tutor having design discussion in the University of Kyrenia (source: author, 2022)

Figure 6.5.7 Comparing the new AR approach to contemporary methods



Source: Compiled by the author, (2023)

Analysis: The new approach to design tutorials in a virtual environment was viewed positively by both tutors and students when compared to traditional methods. The high number of strongly positive responses from students indicates a significant improvement in their learning experience, suggesting that the virtual design studio offers a more engaging and effective way of teaching design.

Statistical Analysis:

Figure 6.5.7 reveals a significant shift in how students and tutors perceived the new AR-based tutorial approach compared to conventional methods used at their universities. Students

overwhelmingly rated the AR experience as “Strongly Positive” ($n = 31$), with an additional 13 selecting “Positive.” Tutors, though fewer in number, mirrored this sentiment—half rated the approach as “Strongly Positive,” and the rest as “Positive.”

From a statistical standpoint, students showed a substantial increase in satisfaction, with scores jumping from a pre-workshop mean of 2.83 (contemporary methods) to 4.11 post-AR experience. This improvement was highly significant ($p < 0.001$, Wilcoxon $V = 12$), indicating that the AR tutorial not only surpassed expectations but may have redefined the benchmark for engagement and clarity in design pedagogy. The ability to walk around, overlay, and interact with digital designs in real-world space provided students with a tangible sense of presence and authorship that is typically missing in traditional 2D critique formats.

Tutors likewise reported a large increase—from 3.53 to 4.68—though with a small sample, the statistical test narrowly missed conventional significance ($p = 0.062$). Nevertheless, the magnitude of change is notable ($\Delta \approx +1.15$), and the consistency of tutor responses implies a strong pedagogical endorsement of AR’s potential. Qualitative feedback supported this, with several tutors commenting that AR allowed them to better “read” student intentions and “step into” proposals in ways not possible with standard CAD reviews or pinned drawings.

The Mann–Whitney U test comparing post-AR satisfaction between groups shows a statistically significant difference in favour of tutors ($U = 10$, $p = 0.004$). While students expressed high satisfaction, tutors rated the AR environment even more favourably—possibly due to their pedagogical framing, which allowed them to instantly recognise the comparative advantage of the new medium. For tutors, AR was not only a tool for review, but a mechanism to enhance clarity, immediacy, and pedagogical dialogue.

When triangulating these findings with your earlier VR data, the VR–AR comparison reveals interesting nuances. For students, VR holds a slight numerical edge in satisfaction, but the difference is not statistically significant ($U = 262$, $p = 0.096$). Tutors, on the other hand, show no meaningful preference between VR and AR ($U = 9$, $p = 0.548$), with both technologies producing

high post-workshop means (≈ 4.60 – 4.68). This suggests pedagogical parity between VR's immersive isolation and AR's contextual integration—each offering a unique but comparably powerful impact on the tutorial experience.

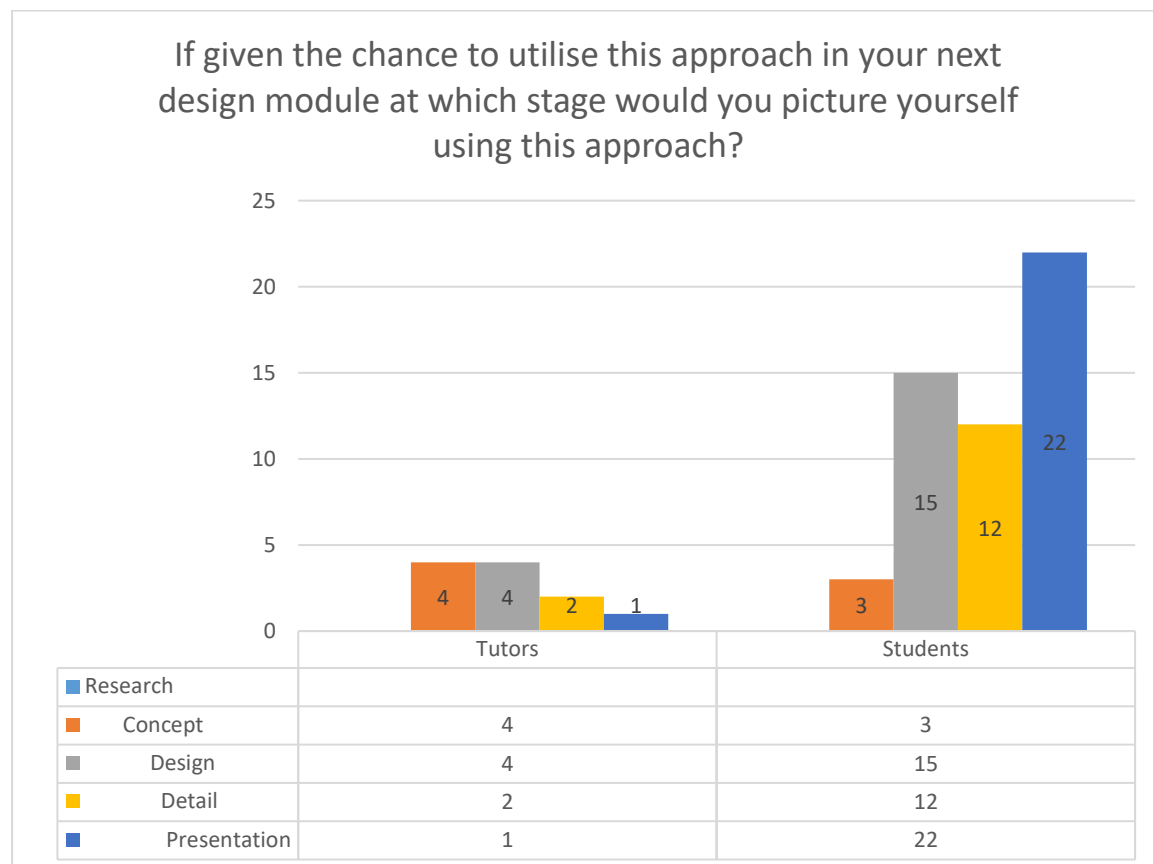
From a theoretical standpoint, this aligns with literature discussed in Chapter 4, particularly the move toward post-digital pedagogy (Oxman, 2006) and the role of experiential interaction in cultivating reflective practice (Schön, 1983). AR doesn't merely replicate studio conditions—it augments them, allowing users to blur conceptual boundaries between drawing and building, thinking and testing.

Key factors contributing to these outcomes include:

- **Real-world contextualisation:** Unlike VR, AR allows designs to be projected onto actual physical spaces, facilitating situated cognition and grounding abstract ideas in tangible reference points.
- **Democratisation of expression:** The data reflects AR's capacity to bring students and tutors closer in their evaluation of effectiveness, supporting earlier claims of AR's role in flattening hierarchical critique structures.
- **Tool maturity and usability:** Induction sessions and intuitive interfaces enabled both groups to quickly develop fluency with the AR tools (e.g., Gravity Sketch, Shapr3D), enhancing confidence and satisfaction.

In conclusion, AR represents a transformative evolution in design education—not only improving engagement and comprehension but doing so in a way that is highly rated by both novice learners and experienced educators. The negligible differences between VR and AR satisfaction scores support the idea that immersive technologies are not a passing trend but a sustainable pedagogical shift—one that educators can adopt flexibly, depending on studio constraints, available equipment, and specific learning objectives.

Figure 6.5.8 Utilising AR in your next design module



Source: Compiled by the author, (2023)

Description:

This figure illustrates the stages of the design process where students and tutors anticipate integrating AR in future modules. The chart reveals a divergence in preferences: students heavily favour AR for the presentation stage, while tutors are more inclined to use it during concept and early design development phases.

Analysis: Tutors and students identified various stages where they would integrate the virtual design studio approach, with a notable preference for the design and presentation stages. This indicates the flexibility of the virtual environment in supporting different phases of the design process and its effectiveness in enhancing the final presentation of work.

Statistical Analysis:

Both groups reported a substantial increase in their intention to use AR in future modules following the workshop. Students' post-experiment scores rose from a mean of 1.35 to 4.37, a statistically significant gain confirmed by the Wilcoxon signed-rank test ($V = 4.5$, $p < 0.001$). Tutors also showed a significant increase, from 2.9 to 3.6, with $V = 0$ and $p = 0.036$.

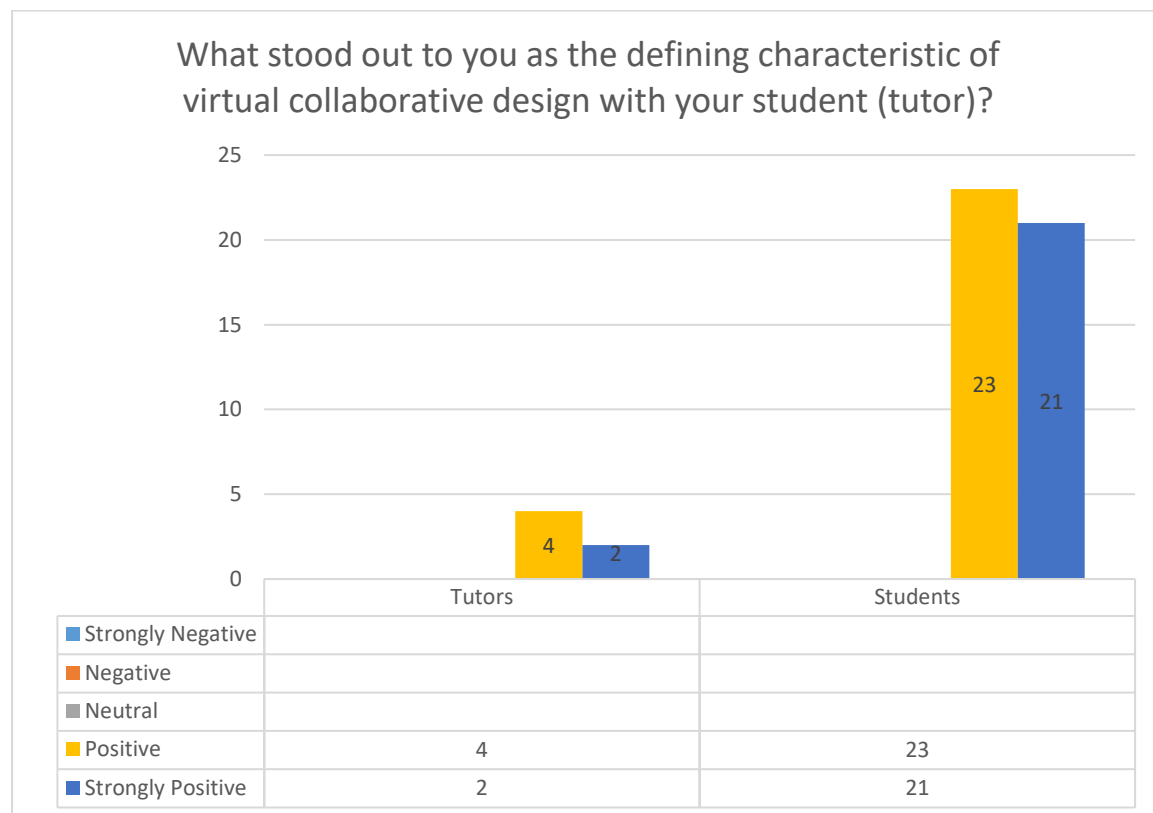
A Mann–Whitney U test comparing post-scores between groups ($U = 415$, $p = 0.001$) indicates that students were significantly more enthusiastic than tutors about continuing AR use in future design modules.

Furthermore, a chi-square test ($\chi^2 = 13.31$, $p = 0.004$) confirms that the distribution of selected design stages differed significantly between the groups. While tutors most often chose AR for the concept and design development phases (40% each), students leaned heavily toward the presentation stage (42%), followed by design (29%) and detail (23%).

These findings reflect differing pedagogical and experiential perspectives. Students, still developing communicative fluency, likely saw AR as a tool for showcasing and explaining their ideas—consistent with literature that emphasises the role of immersive technology in enhancing narrative clarity and confidence (Resnick, 2007; Malinin, 2016). Tutors, on the other hand, viewed AR as a tool for iterative ideation—an interpretation supported by frameworks like Oxman's (2008) model of digital design cognition.

Overall, AR exposure significantly elevated future-use intentions across both groups. The divergence in preferred integration stages reveals AR's versatility: students gravitate toward its communicative power, while tutors embrace its conceptual and spatial affordances. This suggests a valuable opportunity to structure studio workflows that leverage AR at multiple phases, from early ideation to final presentation.

Figure 6.5.9 Defining AR virtual collaborative design characteristic with your student (tutor)?



Source: Compiled by the author, (2023)

Description: This figure highlights which aspects of virtual collaboration stood out to students and tutors during the AR workshops. The focus was on the defining features of collaborative interaction in a mixed-reality studio setting, capturing changes in perception pre- and post-intervention.

Analysis: Participants highlighted the collaborative nature of the virtual design studio as its defining characteristic. The high number of positive responses underscores the importance of collaboration in the design process and the effectiveness of the virtual environment in facilitating teamwork and communication.

Statistical Analysis:

Students showed a substantial increase in their perception of virtual collaboration, rising from a pre-workshop mean of 2.75 to a post-AR mean of 4.48. This gain was highly significant ($V = 0, p < 0.001$) and represents a large effect size. Tutors also experienced a statistically significant improvement from 3.33 to 4.33 ($V = 0, p = 0.034$), though starting from a higher baseline.

Post-workshop comparison between the two groups yielded no significant difference ($U = 151, p = 0.522$), suggesting that students' attitudes rose to match those of tutors, effectively closing the experience gap.

These results underscore that AR can serve as an equalising force in design education, elevating novices to the collaborative confidence levels of more experienced tutors. This aligns with emerging literature on technology-mediated flattening of traditional power structures in studio pedagogy (Schnabel, 2020; Wang et al., 2021).

- Technological Affordances:

AR enabled synchronous, co-located interaction with virtual content, allowing both students and tutors to manipulate models, annotate, and explore spatial ideas together in real-time. This reinforced shared mental models—a critical aspect of effective teamwork as outlined by Salas et al. (2008).

- Role-Modelling and Social Learning:

Tutors' engagement in the collaborative environment may have served as a model for students, reinforcing norms of active participation. This mirrors principles from Vygotskian learning theory, where social interaction with more experienced peers accelerates cognitive development (Vygotsky, 1978).

- Structured Collaborative Tasks:

The workshop structure, likely designed around co-design challenges, played a key role. Tasks requiring joint decision-making and peer-to-peer feedback made collaboration

both necessary and meaningful—an element consistently associated with deeper learning in immersive education (Radianti et al., 2020).

- **Novelty and Engagement:**

While AR's novelty may have initially sparked excitement, the consistency in post-scores across participants suggests that the boost in collaboration perception was not merely superficial. The dual coding of spatial and verbal input in AR likely contributed to this effect, making abstract ideas easier to discuss and negotiate (Paivio, 1990).

- **Communication Clarity:**

By allowing participants to share a hybrid physical-virtual space, AR removed much of the ambiguity present in traditional 2D communication. Being able to point, rotate, and annotate directly on models supports embodied cognition, helping learners externalise and negotiate ideas more fluently (Wilson, 2002).

In summary, AR workshops significantly improved collaboration perceptions among both students and tutors, with students showing particularly large gains. The technology's spatial and interactive affordances, combined with a structured and socially supportive environment, helped create a powerful platform for design teamwork. This reinforces the argument for embedding AR tools in collaborative segments of architectural education, not only to facilitate co-creation but to enhance interpersonal learning dynamics across all experience levels.

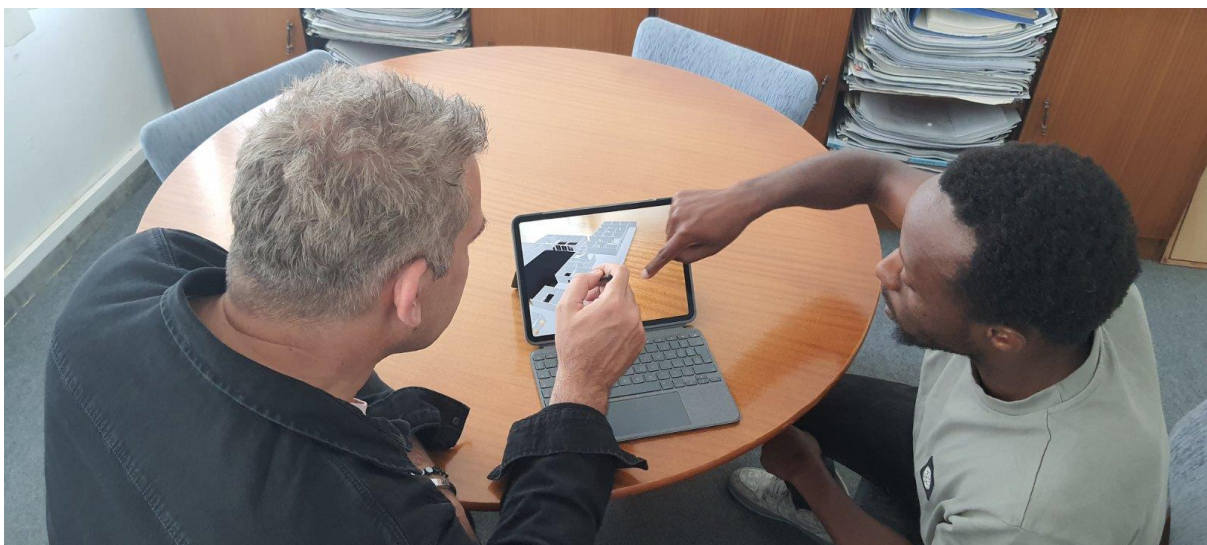
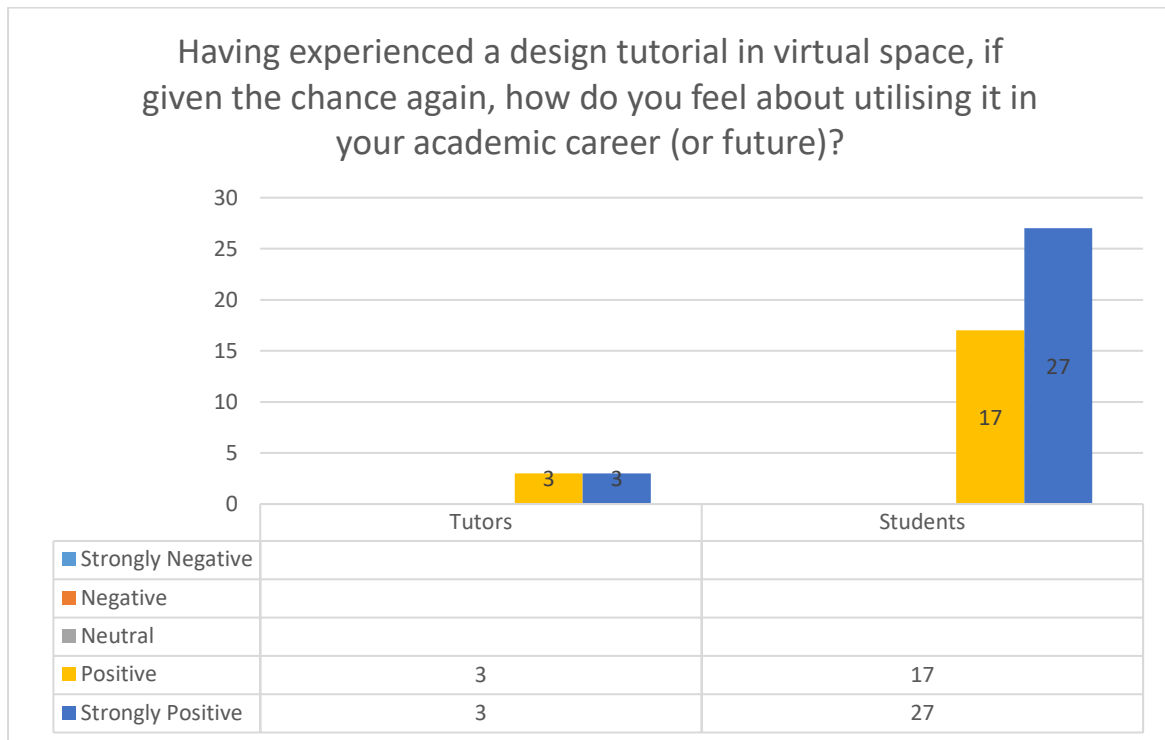


Image 6.5.5 Student and Tutor having design discussion in Near East University (source: author, 2022)

Figure 6.5.10 Utilising AR in your academic career (or future).



Source: Compiled by the author, (2023)

Analysis: Both tutors and students expressed a strong preference for using virtual design tutorials again in the future. The overwhelmingly positive feedback indicates that the virtual design studio is a valuable addition to the architectural education toolkit, offering a more immersive and engaging learning experience.

Statistical Analysis:

Following their participation in the AR design tutorials, both students and tutors reported a strong inclination to continue using augmented reality in their future academic or professional contexts. This overwhelming positivity reflects not only a successful workshop experience but also a shift in perception regarding the long-term value of AR within architectural education and practice.

Students, in particular, experienced a dramatic transformation in attitude. Their mean rating increased from a modest 1.80 pre-workshop to a highly enthusiastic 4.61 post-workshop, a statistically significant improvement ($p < 0.001$). This change suggests that many students approached the workshop with a degree of scepticism or unfamiliarity, perhaps reflecting concerns over usability, relevance, or technical barriers. However, once immersed in the AR environment, these concerns appeared to dissipate rapidly. Students discovered the practical applications of AR for design thinking, communication, and presentation, leading to a genuine embrace of the technology. Their shift also speaks to the broader digital turn in education, where immersive tools are increasingly recognised as integral to developing future-ready skills in the design disciplines.

Tutors also showed a marked increase in their intention to use AR in future contexts, rising from 2.67 to 4.50 ($p = 0.031$). While the magnitude of change was slightly smaller than that observed in students, this is likely due to the tutors' higher starting baseline. As professionals more familiar with emerging digital tools, tutors were perhaps already aware of AR's potential but had not yet seen it enacted within a structured pedagogical setting. The workshop offered them direct evidence of AR's benefits—particularly its impact on student engagement, communication clarity, and the ability to visualise and critique spatial ideas collaboratively. Their post-workshop ratings confirm that AR is not just a novel adjunct, but a serious tool with viable applications in design education.

Interestingly, despite these different starting points, both groups converged at similarly high levels of post-workshop enthusiasm, with no statistically significant difference between them ($p = 0.61$). This convergence suggests that once users—regardless of experience level—have the opportunity to explore AR in a meaningful, hands-on context, their perspectives tend to align. The AR experience was sufficiently robust, intuitive, and rewarding to appeal across generational and professional divides, highlighting its potential for widespread adoption in studio-based learning environments.

This finding also triangulates with earlier results in Figures 6.5.8 and 6.5.9, where students consistently showed more dramatic gains from pre- to post-AR exposure, but ultimately aligned with tutors in their final evaluations. The pattern reflects a common trajectory in technology adoption: initial uncertainty followed by enthusiastic uptake once users experience the tool's relevance and accessibility. For students, AR offered a glimpse into the evolving nature of professional practice—one in which digital literacy and spatial computing may play increasingly central roles. For tutors, the workshop reinforced AR's pedagogical validity, not only as a medium for content delivery but as a platform for fostering creativity, collaboration, and critical reflection. In sum, the results from Figure 6.5.10 highlight AR's potential to serve as a bridge between current pedagogical practices and future professional realities. Both students and tutors emerged from the workshop as advocates for continued use, confirming that immersive technology, when properly introduced and scaffolded, can foster long-term engagement and perceived value. This supports the case for further integration of AR into architectural curricula—not merely as a technological enhancement, but as a tool for reimagining how design is taught, communicated, and experienced.

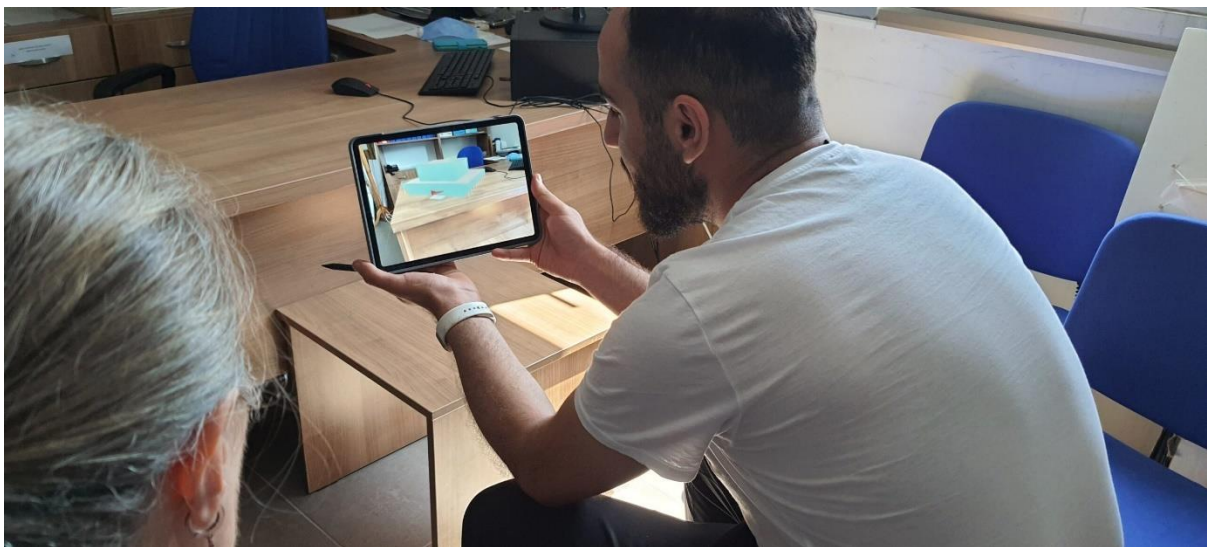
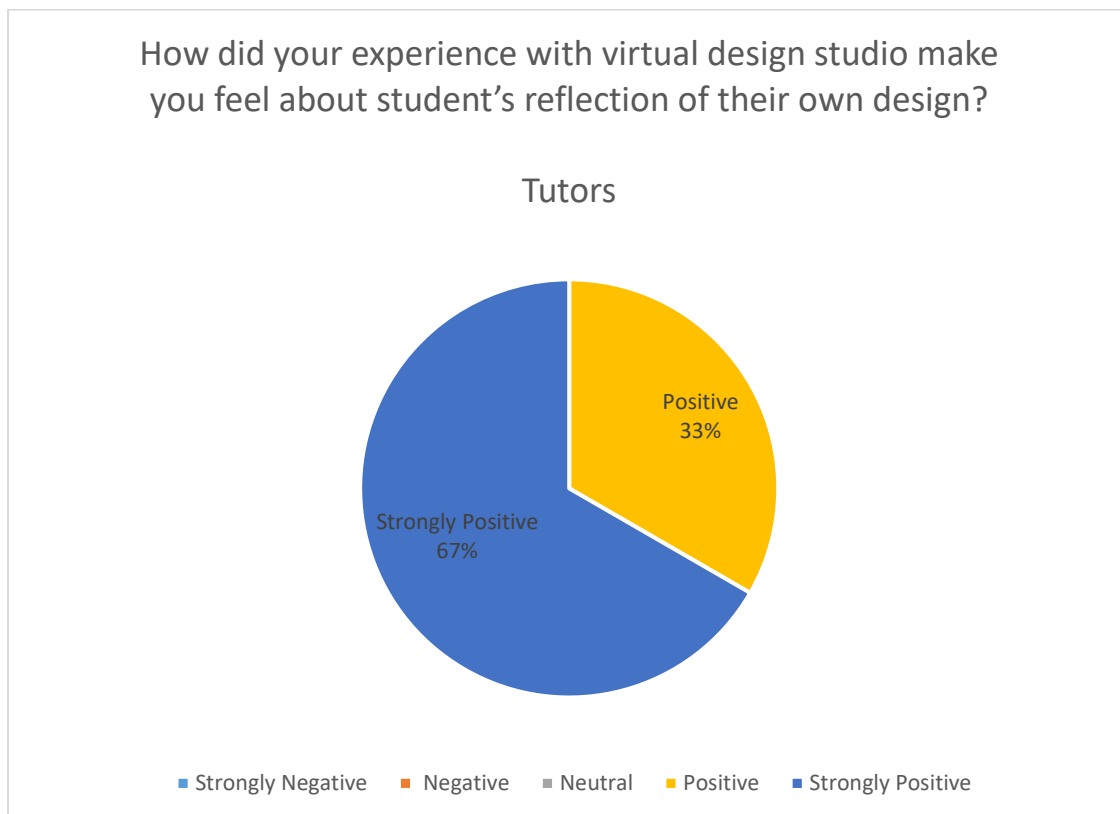


Image 6.5.6 Student describing their design idea with their tutor in the University of Kyrenia (source: author, 2022)

Figure 6.5.11 Impact of AR on students' reflection of their own design



Source: Compiled by the author, (2023)

Analysis: Tutors felt that the virtual design studio positively impacted students' ability to reflect on their own designs. This suggests that the virtual environment encourages deeper critical thinking and self-assessment, essential skills in the design process.

Conclusion

The analysis of these additional graphs reaffirms the positive impact of virtual design studios on architectural education. Both tutors and students appreciated the virtual environment's enhanced collaboration, creativity, and overall learning experience. The data suggests a strong preference for continuing to use these technologies in future academic and professional settings

Commentary

The AR workshop highlighted the advantages of AR technology in facilitating effective communication and speeding up design iterations. The real-time overlay of digital information onto the physical world provided a tangible and intuitive way for students and tutors to interact with design concepts. This experiment reinforced the importance of integrating AR tools into the design education process to enhance creativity, communication, and confidence among students and tutors.

6.6 Findings from the AR Experiment

The findings from the AR experiment provide valuable insights into the impact of augmented reality on architectural education. The data collected through quantitative and qualitative methods shed light on how AR influences key areas of creativity, communication, confidence, and competence in design. Below, the findings are presented, integrating both statistical data and thematic analysis to offer a comprehensive understanding of the results.

6.6.1 Creativity

Quantitative Findings:

The Likert-scale questionnaires revealed a significant increase in participants' perceived creativity when using AR tools. Pre-experiment scores indicated moderate levels of creative confidence, with an average score of 3.2 (on a 5-point scale). Post-experiment scores showed an increase to 4.3, indicating a notable enhancement in participants'

creative confidence. This aligns with the literature on AR's ability to foster immediate feedback and dynamic interaction, as discussed in Chapter 3 (Martín-Gutiérrez et al., 2015).

Qualitative Findings:

The thematic analysis of interview transcripts further supported these findings. Several participants reported that AR allowed them to "visualize their designs in ways that traditional tools could not." One participant noted, "I was able to see how my design fit into the physical environment and make adjustments in real-time." Another participant mentioned that "the instant feedback from AR helped me try out different design ideas without having to restart or undo previous work," echoing the literature on AR's capacity to foster iterative creativity (Sánchez-Sepúlveda et al., 2019).

The interviews highlighted that AR's unique ability to overlay digital elements onto the physical world made the design process more tangible and intuitive. This immersive interaction helped participants experiment with various design concepts more freely, fostering a deeper sense of creative exploration (Akil et al., 2020).

6.6.2 Communication

Quantitative Findings:

Participants' communication scores also saw a significant increase. Pre-experiment questionnaires averaged a communication score of 3.5, which rose to 4.4 in post-experiment responses. This improvement aligns with earlier studies that suggest AR

enhances design communication by enabling real-time model manipulation during discussions (Linh, 2020).

Qualitative Findings:

The interviews revealed that AR facilitated more dynamic and interactive communication between students and tutors. One tutor stated, "Being able to manipulate the design model during our discussions made it easier to point out areas that needed improvement." Students also echoed this sentiment, with one participant explaining, "The ability to see and adjust the model as we talked made the design critique much more engaging and productive."

Thematic analysis identified two key factors that contributed to improved communication:

1. **Real-time Interaction:** The ability to manipulate 3D models during discussions was repeatedly cited as a major advantage, allowing both students and tutors to better articulate their ideas and design critiques.
2. **Enhanced Visualization:** By providing an immersive visual context, AR helped bridge gaps in understanding between students and tutors, allowing for clearer and more effective communication (Diao & Shih, 2019).

6.6.3 Confidence

Quantitative Findings:

Confidence levels in using design tools also saw improvement, rising from an average pre-experiment score of 3.0 to 4.1 post-experiment. This suggests that AR not only fostered creative exploration but also boosted students' confidence in their design abilities and their presentations during critiques (Saadon et al., 2020).

Qualitative Findings:

The interviews supported these quantitative results, with students reporting that the immersive nature of AR gave them a greater sense of control over their designs. One participant noted, "I felt more confident showing my design because I could interact with it and demonstrate how it would work in a real-world setting."

Tutors also observed increased confidence among students when presenting their work. One tutor remarked, "The students seemed more assured when explaining their designs in AR. It was as if being able to see the design in front of them gave them a stronger sense of ownership and understanding."

Thematic analysis highlighted that this increase in confidence was linked to the **tangible interaction** that AR facilitated. By allowing students to engage with their designs in a more hands-on way, AR helped demystify complex architectural concepts and reduced the anxiety that often accompanies traditional design presentations (Hajirasouli & Banihashemi, 2022).

6.6.4 Competence

Quantitative Findings:

In terms of competence, participants reported a significant increase in their perceived ability to use AR tools effectively. Pre-experiment scores averaged 2.9, rising to 4.0 in post-experiment responses. This suggests that AR can be an effective learning tool for developing technical competence in architectural design.

Qualitative Findings:

Interviews revealed that participants felt more competent in using AR tools after the experiment. One student noted, "At first, I was unsure about how to use AR, but after a few sessions, I felt like I had mastered the basics and could use it to improve my designs." Another student commented, "Learning AR was challenging at first, but it became second nature by the end of the experiment. I feel like I could apply this in my future design projects."

Tutors also observed improvements in students' competence with AR technology. One tutor explained, "The students became more proficient with AR as the experiment progressed. By the final design review, they were using AR tools with confidence and skill."

6.7 Summary of Findings

The AR experiment demonstrated that AR tools have the potential to enhance architectural education significantly. The findings suggest that AR can improve creativity, communication, confidence, and competence in architectural design by offering a more interactive and immersive learning environment. These findings are consistent with previous literature on the pedagogical benefits of AR, reinforcing the argument that AR

can play a transformative role in architectural education (Martín-Gutiérrez et al., 2015; Diao & Shih, 2019).

6.8 Discussion

The findings from the AR experiment indicate the potential of augmented reality (AR) to enhance interactivity and immersion in architectural education. Specifically, AR appears to support key educational outcomes such as creativity, communication, confidence, and competence. Rather than claiming that AR significantly transforms architectural pedagogy, these findings highlight AR's utility as a design medium within experimental learning environments. This section evaluates the results in light of the existing literature and draws connections to the theoretical discussions and pedagogical challenges outlined in Chapters 2, 3, and 4. It also reflects on the limitations of the study, including its relatively small sample size, short duration, and varying levels of participants' prior exposure to AR.

6.8.1 Creativity and Iterative Design

This experiment suggests that AR contributes positively to students' creative development, especially within iterative design workflows. Creativity scores increased from 3.2 to 4.3, indicating a self-perceived improvement in the ability to explore and refine ideas. As emphasized in Chapter 2, creativity in architectural pedagogy is closely tied to iterative processes and reflection (Schön, 1987). AR facilitates this by allowing students to dynamically manipulate and visualize their designs in real time.

By enabling immediate design modifications and offering a spatial interface for exploration, AR aligns with Schön's concept of reflective practice. In this context, students are not passive recipients of critique but active participants in an evolving design dialogue—one that encourages real-time experimentation and adjustment (Schön & Wiggins, 1992). This mirrors what Sánchez-Sepúlveda et al. (2019) describe as AR's potential for supporting visual learning and spatial problem-solving.

However, it is worth noting that the short-term nature of the study limits our understanding of how sustained AR use might influence long-term creative development or the depth of iterative learning cycles.

6.8.2 Communication and Collaborative Learning

Communication scores rose from 3.5 to 4.4, reinforcing the proposition that AR tools may enhance design communication and feedback loops. The ability to collaboratively review and manipulate shared models in real-time created more engaging discussions between students and tutors during critiques. These findings echo existing research (e.g., Birt et al., 2018) that positions AR as a facilitator of collaborative and visual dialogue.

In the context of pedagogical theory, AR helps mitigate the abstract nature of architectural concepts by making spatial relationships and material interactions more tangible—an important feature discussed in Chapter 3 (Linh, 2020). The enhancement of shared visual understanding in design communication is particularly valuable in

addressing some of the traditional barriers in studio learning, such as the difficulty in conveying spatial ideas through static media.

Yet, the study did not directly compare AR-based critique sessions with traditional formats, and the scope was limited to a specific cohort and timeframe. Further comparative analysis is necessary to determine whether AR's benefits persist in more complex or high-stakes design review settings.

6.8.3 Confidence in Design Presentation

Confidence levels improved from 3.0 to 4.1 post-workshop, suggesting that AR tools may ease presentation anxiety and support more assertive engagement during critiques. As noted in Chapter 2, the abstract and often high-pressure nature of traditional presentations can discourage some students from articulating their ideas effectively.

The immersive interface of AR empowers students to 'show' rather than merely 'tell', thereby reinforcing their self-efficacy and understanding of spatial dynamics (Hajirasouli & Banihashemi, 2022). This supports the argument from Chapter 3 that immersive technologies foster more confident, embodied forms of communication.

Nevertheless, confidence can be a subjective and fluctuating measure. This study did not assess long-term retention or whether this boost in confidence translated into improved performance or deeper learning outcomes.

6.8.4 Competence in Using AR Tools

Competence scores increased from 2.9 to 4.0, suggesting that students became more comfortable with the technical aspects of AR. This aligns with the broader call in Chapter

4 for curricula to include emerging digital tools and supports the argument by Bremer (2007) regarding the need to modernize architectural education.

The hands-on experience provided in the workshop helped students learn how to navigate and operate AR design platforms. It also addressed a known barrier to adoption—namely, the steep learning curve associated with unfamiliar tools. These findings are consistent with Martín-Gutiérrez et al. (2015), who found that immersive tools help develop spatial competence and technological fluency when introduced within a structured pedagogical framework.

Still, participants entered the workshop with varying levels of prior exposure to AR, and the results should be interpreted with caution. Longitudinal studies would be necessary to assess the retention of technical skills and their transferability to professional settings.

6.8.5 The Role of Immersive Technologies in Architectural Education

Overall, this experiment provides promising but preliminary evidence that AR may support the pedagogical aims of architectural education, particularly in terms of enhancing interactivity and engagement. As discussed in Chapter 2, architecture as a discipline struggles with conveying abstract concepts and teaching spatial reasoning through traditional media. AR addresses some of these challenges by creating embodied, real-time learning opportunities.

These results align with the experiential, student-centred pedagogies introduced in Chapter 3, which advocate for immersive learning environments. They also reinforce the

argument in Chapter 4 that immersive technologies should be positioned not as supplements but as design mediums, capable of supporting the core aims of studio education.

However, it is essential to view these findings within the limitations of the current study. While the results suggest promising directions, broader and longer-term studies are needed to determine the full pedagogical value and scalability of AR in architectural education. Future research should focus on curriculum integration, tutor training, and evaluating the long-term cognitive and creative impacts of immersive design environments.

6.9 Conclusion

The AR experiment demonstrated that augmented reality holds significant potential for enhancing architectural education. By improving creativity, communication, confidence, and competence, AR provides a powerful tool that can transform the way design is taught and practiced. These findings build on the discussions from Chapters 2, 3, and 4, reinforcing the argument that immersive technologies offer a unique opportunity to modernize architectural pedagogy and address the challenges of teaching spatial relationships and design thinking.

Future research should continue to explore the long-term impact of AR in architectural education, particularly in terms of how it influences students' professional development and design skills. Additionally, efforts should be made to ensure that AR tools are accessible to all students, regardless of their technical background, to maximize the educational benefits of this transformative technology.

Chapter 7: Experiment 3: Mixed Reality (MR) Semester Project

7.0 Overview

The third experiment extended the use of immersive technologies over a full semester, combining VR, AR, and MR tools (Arkio, Gravity Sketch, Shapr3D). The aim was to assess the long-term impact of these technologies on design education and project outcomes. Participants included third and fourth-year undergraduate architecture students from the Final University, University of Kyrenia, and Near East University. The objective was to familiarize students and tutors with MR technology and assess its impact on design discussions and project development. The number of student participants for this group was 60 and the number of tutor participants was 6.

7.1 Introduction

The integration of Mixed Reality (MR) into architectural education represents a significant step forward in bridging the gap between digital tools and physical spatial understanding. MR, which combines the immersive qualities of Virtual Reality (VR) and the interactive nature of Augmented Reality (AR), allows users to interact with digital and physical elements simultaneously. This duality presents a unique opportunity for educators and students in architectural education, where understanding spatial relationships and real-time design feedback are crucial (Speicher et al., 2019).

The role of immersive technologies in education has been discussed extensively in the literature. As highlighted in Chapter 2, traditional architectural pedagogy has historically relied on studio-based, experiential learning models. These models, pioneered by the École des Beaux-Arts and other historical schools, emphasized hands-on learning,

reflection, and critique as the primary methods for developing design skills (Salama, 2016). However, the introduction of digital tools—from early CAAD systems to modern VR and AR—has expanded the educational landscape, allowing for new forms of learning and interaction (Dorta et al., 2016). Chapter 3 delves into how Virtual Reality (VR) and Augmented Reality (AR) have been employed in architectural education, facilitating creative exploration and enhancing communication between students and tutors (Birt et al., 2018). The move towards Mixed Reality builds on these foundations, providing an even more integrated approach to design.

MR offers several pedagogical advantages over traditional tools, as it allows students to experience their designs in a contextually rich environment, blending physical and digital worlds (Gül & Gu, 2019). This is particularly important in architecture, where understanding spatial relationships, light, and materiality is critical to the success of a design. Chapter 4 introduced the theoretical framework behind the use of immersive technologies, highlighting the need for tools that support reflective practice, iterative feedback, and collaborative learning (Schön, 1987). The integration of MR addresses these needs by allowing students to seamlessly transition between digital and physical spaces, fostering a more holistic understanding of their designs.

However, the adoption of MR in architectural education is not without challenges. Previous research, as discussed in Chapter 4, has identified several barriers to the effective implementation of immersive technologies in education, including technical limitations, high costs, and the need for extensive training. While Ansar & Khan (2016) first highlighted these obstacles nearly a decade ago, recent studies continue to report similar challenges, especially in contexts where institutional infrastructure and digital

literacy levels are uneven (e.g., Christopoulos et al., 2018; García-Holgado et al., 2020). Despite advancements in hardware and software accessibility, these issues remain particularly salient in higher education settings adopting MR for the first time. Additionally, the novelty of MR technology still demands new pedagogical strategies and support mechanisms to fully harness its potential (Diao & Shih, 2019).

In this chapter, the impact of MR on architectural education will be explored through a semester-long experiment, examining how it influences students' creativity, communication, confidence, and competence. Drawing on insights from Chapter 3, which discussed the application of immersive technologies in educational settings, this study seeks to build on previous research while addressing the unique capabilities of MR. By providing students with a mixed environment where they can interact with both physical and digital elements, this experiment aims to assess how MR can enhance the learning process in architectural education.

The research questions posed in this chapter are rooted in the theoretical frameworks presented in earlier chapters. Specifically, the study seeks to address the following questions:

1. How does MR impact creativity and problem-solving in architectural design?
2. What is the role of MR in enhancing communication between students and tutors during the design process?
3. How does long-term exposure to MR affect students' confidence and competence in using advanced design tools?

These questions build on the gaps identified in Chapter 3, where the potential of MR to foster collaboration and real-time feedback was acknowledged but had not been thoroughly examined within architectural education. To address this, the research methodology was adapted to take full advantage of the extended timeframe: the experiment was conducted over the course of an entire semester, allowing students to engage with MR tools in multiple design phases—ideation, iteration, presentation, and feedback. This extended contact allowed for the collection of longitudinal data through three waves of questionnaires and recurring observations, as well as more in-depth post-experiment interviews. It also enabled a progressive integration of MR into the curriculum, from initial tutorials and low-stakes exercises to full project applications, thus facilitating a more accurate evaluation of how familiarity and confidence with MR evolved over time.

7.2 Research Questions and Objectives

As previously mentioned, the primary aim of this study is to explore the pedagogical potential of Mixed Reality (MR) within the context of architectural education. Drawing on the insights from Chapter 2 and Chapter 3, this study seeks to examine the specific ways MR can influence core aspects of architectural education: creativity, communication, confidence, and competence.

The evolution of architectural pedagogy, as discussed in Chapter 2, has shown that traditional learning methods, while effective, may not be sufficient to address the challenges posed by modern design technologies (Salama, 2016). In particular, there is a need for educational tools that enhance spatial understanding, support collaborative learning, and allow students to visualize their designs in real-time. MR technology

provides an opportunity to bridge this gap by offering immersive and interactive environments that integrate both digital and physical elements (Speicher et al., 2019).

In Chapter 3, the use of immersive technologies such as VR and AR was explored, with several studies highlighting their positive impact on creativity and design thinking (Birt et al., 2018). However, while these technologies have shown promise, there is still limited research on the long-term effects of MR on architectural education, particularly in terms of student confidence and competence. This chapter, therefore, seeks to address this gap by conducting a semester-long experiment that evaluates the impact of MR on key learning outcomes.

7.2.1 Research Questions

The following research questions guide this study, each addressing a specific aspect of Mixed Reality's (MR) impact on architectural education. These questions are directly aligned with the overarching research objectives set out in Chapter 1, which aim to assess how immersive technologies influence creativity, communication, and confidence in design education.

1. How does MR influence creativity and design thinking in architectural education?
 - This question builds upon the first and second research questions identified in Chapter 1, which focus on understanding how immersive technologies affect creative thinking and design development. Specifically, this question explores the ways in which MR enhances students' ability to conceptualize, iterate, and develop innovative design solutions. MR, by enabling real-time interaction with both digital and

physical design elements, is expected to promote deeper creative engagement and experimental design thinking (Huang et al., 2018). This expands on the findings from Chapter 3, where immersive technologies were shown to stimulate creativity through dynamic spatial environments (Abdelhameed, 2011).

2. How does MR facilitate communication and collaboration between students and tutors?

- This question corresponds to the third research question from Chapter 1, which addresses communication efficacy in virtual learning environments. Communication and feedback are central to studio-based education, and MR offers a collaborative medium through which students and tutors can jointly interact with 3D models in real-time. The study investigates how this shared virtual space impacts design discussions, critiques, and the articulation of spatial ideas. Chapter 3 and related studies (e.g., Gül & Gu, 2019; Bartosh & Anzalone, 2019) suggest that MR may enhance the clarity and depth of such exchanges.

3. How does long-term exposure to MR impact student confidence and competence in using advanced design tools?

- This question is a direct continuation of the fourth research question from Chapter 1, which explores how immersive technologies affect student confidence and reflective abilities. While previous experiments (e.g., VR and AR workshops) provided short-term exposure and yielded immediate post-intervention feedback, this MR experiment extends the exposure over an entire semester, allowing for a more nuanced understanding of how

confidence and technical competence develop over time. The short-term benchmark is derived from the earlier VR and AR workshops, where students engaged with immersive tools over a two-week period. These prior results serve as a comparative baseline to evaluate whether prolonged engagement with MR tools results in greater self-efficacy and proficiency, particularly in applying these tools to complex, iterative design tasks (Zhang et al., 2018). This also links back to Schön's (1987) theory of reflective practice, which emphasizes sustained interaction and feedback as core components of architectural learning.

7.2.2 Research Objectives

This chapter adopts a clearly articulated objectives structure to reflect the extended scope and duration of the Mixed Reality (MR) experiment, which differs from the shorter, exploratory workshops conducted in Chapters 5 (VR) and 6 (AR). The semester-long implementation of MR allowed for more sustained observation and a deeper analysis of its pedagogical impacts, warranting a more structured breakdown of the research aims at this stage.

While the objectives in this section are indeed derived from the previously stated research questions (Section 7.2.1), they serve a distinct purpose. The research questions outline the broader inquiries guiding this chapter, whereas the objectives translate those inquiries into concrete analytical goals. These objectives are designed to align with the mixed-methods research strategy outlined in Chapter 4, ensuring a consistent and focused interpretation of both quantitative and qualitative data.

The specific objectives of this MR study are:

1. To evaluate the impact of MR on creativity and problem-solving in architectural design.
 - This objective aims to assess how the extended use of MR affects students' creative development and their ability to explore innovative design solutions. Using both pre- and post-experiment surveys and thematic analysis of interviews, the study seeks to determine whether MR fosters more exploratory, iterative, and reflective design behaviour, as theorised by Schön (1987) and further discussed in Chapter 3.
2. To assess the effectiveness of MR in enhancing communication and feedback during design critiques.
 - Building upon previous findings related to VR and AR, this objective specifically investigates how MR platforms influence the quality of tutor-student interactions in a collaborative studio context. By examining communication dynamics during MR-enabled sessions, this objective tests the assumption that immersive environments support more immediate, intuitive, and spatially-grounded design dialogue (Dorta et al., 2016), as explored in Chapter 3.
3. To analyze the long-term effects of MR on student confidence and competence in using advanced design tools.
 - Unlike the short-term workshops in Chapters 5 and 6, the MR experiment provides an opportunity to evaluate whether prolonged exposure

enhances students' self-efficacy and skill acquisition. This objective focuses on understanding whether continued use of MR correlates with improved confidence in presenting ideas and higher competence in employing immersive technologies for complex design challenges, as discussed in Radi et al. (2021) and Chapter 3.

By clearly defining these objectives, the chapter not only ensures alignment with the broader aims of the thesis (Chapter 1), but also contributes practical, evidence-based insights into how MR can be meaningfully embedded in future design education curricula. By addressing these research questions and objectives, this study aims to contribute to the growing body of literature on immersive technologies in architectural education. Additionally, it seeks to provide practical insights for educators on how MR can be effectively integrated into design studio curricula, building on the theoretical frameworks and empirical findings presented in previous chapters

7.3 Tools Used in the Experiment:

The tools used in this Mixed Reality (MR) experiment combined hardware and software technologies, which allowed participants to interact with both virtual and physical elements of their architectural designs. MR tools, such as Gravity Sketch, Shapr3D, and Arkio, were integral to facilitating the immersive experience throughout the semester. These platforms were selected based on their ability to merge the immersive qualities of VR with the contextual awareness of AR, creating a cohesive environment for students to engage with the design process at multiple levels of interaction.

Gravity Sketch was particularly effective in the VR environment as it allowed students to explore their designs in a fully immersive 3D space. By enabling real-time modifications and providing intuitive design tools, Gravity Sketch aligned with the principles identified in Chapter 3, where VR technologies were discussed as enhancing spatial understanding and improving creativity (Bartosh & Anzalone, 2019). The ability to walk through designs offered participants a new perspective on their projects, which enhanced their confidence in conceptualizing and communicating complex architectural ideas (Dorta et al., 2016).

Shapr3D, a mobile-first 3D modeling app, was used for its compatibility with both iPads and desktop environments. Shapr3D allowed students to manipulate detailed architectural models on their personal devices, supporting real-time feedback in both the VR and AR phases of the semester-long experiment. As noted in Chapter 2's exploration of CAD and CAAD systems, Shapr3D provided a flexible platform for design that aligned well with contemporary digital architectural tools.

Arkio was used to bridge the VR and AR components, allowing participants to work collaboratively in MR. This tool enabled real-time collaboration, where students and tutors could work simultaneously on different aspects of a design project. By incorporating feedback from multiple stakeholders during the design process, Arkio's integration of AR for field analysis and VR for immersive design enhanced the collaborative experience, as discussed in Chapter 6. It also served to facilitate communication between students and tutors, which was one of the critical elements measured in this experiment.

By utilizing these technologies, the MR experiment was able to balance the practical needs of architectural education with innovative pedagogical strategies. The integration of tools like Gravity Sketch and Arkio, which provided both immersive and collaborative environments, aligned with research from Chapter 4 that emphasized the role of MR in enhancing student engagement and learning outcomes (Azhar & Kouider, 2021). As the literature suggests, the combination of immersive environments and real-time collaboration supported iterative design practices, which are central to the architectural learning process (Gül & Gu, 2019).

These tools were also chosen based on their alignment with the research questions posed in this study, focusing on creativity, communication, confidence, and competence. The MR platforms allowed students to engage in active learning, drawing on theoretical insights from Chapter 3 on experiential and collaborative learning in architecture, reinforcing the educational value of MR technology.



Image 7.3.1 Total of 2 sets of Oculus Quest VR headsets were used for the MR experiment.



Image 7.3.2 iPad Pro 11 inch screen 2022 version(left) and Apple Pen (Right) used for the AR experiment.

7.4 Methodology for the MR Experiment

This section outlines the research design, data collection methods, and analytical strategies employed in the Mixed Reality (MR) experiment. The goal of the experiment was to assess the impact of MR on students' creativity, communication, confidence, and competence in architectural design, in line with the research questions posed in Section 7.1. The methodology draws on mixed-methods research principles (Creswell & Plano Clark, 2017), integrating both quantitative and qualitative data to provide a comprehensive analysis of the MR environment's effects on architectural education.

7.4.1 Participants

The participants for the MR experiment were undergraduate and postgraduate students enrolled in architecture courses across three universities. A total of 36 students and 6 tutors were selected based on their familiarity with basic design tools and their willingness to engage in immersive technologies. Prior to the experiment, students completed a pre-experiment questionnaire that assessed their baseline creativity, communication, confidence, and competence using traditional design tools.

Participants were divided into three groups based on their academic year and prior exposure to VR and AR technologies:

1. First-year undergraduate students (12 participants): These students had minimal prior experience with immersive technologies and were introduced to MR for the first time.
2. Final-year undergraduate students (12 participants): This group had intermediate experience with VR and AR, having previously used these tools in design projects.

3. Postgraduate students (12 participants): The postgraduate group had advanced exposure to both VR and AR, and the MR experiment built on their existing knowledge.

Each group participated in the semester-long MR experiment, allowing for a longitudinal analysis of how their design skills evolved over time. The choice to include participants with varying levels of experience aligns with findings from Chapter 2 on the importance of tailoring educational interventions to students' developmental stages (Salama, 2016).

7.4.2 Experimental Design

The Mixed Reality (MR) experiment was carried out over the course of a 12-week architectural design studio module, integrated into the regular semester curriculum. The primary aim was to evaluate how the integration of immersive technologies—specifically VR and AR—could influence students' design development, communication, confidence, and competence. The experiment employed a progressive pedagogical structure, where each week's tasks incrementally built upon the previous, fostering both technical and conceptual growth.

Project Brief:

Students were tasked with designing a small-scale public building (e.g., a pavilion, exhibition space, or community hub) situated within a real-world urban context. The brief emphasized both functional and experiential qualities of architectural space, encouraging students to consider spatial circulation, lighting, materiality, environmental context, and user interaction. The complexity of the brief was calibrated to the skill levels

of second- and third-year architecture students, ensuring it was sufficiently challenging while remaining achievable within the semester.

The design brief was developed collaboratively with tutors across three participating institutions to ensure academic alignment and clarity. It was introduced during Week 1 through an orientation session, which included a walkthrough of the project's aims, assessment criteria, and a demonstration of the MR technologies that would be used. Supporting materials—including site analysis documents, precedent studies, and conceptual design prompts—were provided digitally via a shared platform.

Delivery & Structure:

The semester was divided into three key phases:

1. Exploratory Phase (Weeks 1–4):

Students were introduced to MR tools such as Gravity Sketch, Shapr3D, and Arkio. Early design exercises focused on spatial exploration, conceptual sketching in immersive environments, and experimenting with form and scale. Tutorials and technical training sessions were provided to ensure basic fluency with the tools.

2. Development Phase (Weeks 5–9):

Students began developing their architectural proposals in detail. The MR platforms allowed real-time feedback from tutors and peers. Weekly pin-ups and crits were held in both physical and virtual environments, emphasizing iterative development, spatial understanding, and narrative building.

3. Refinement & Presentation Phase (Weeks 10–12):

Final designs were refined using both digital and physical modelling workflows. Students prepared immersive presentations of their projects, allowing for walkthroughs and real-time modifications within the MR environment. Tutors assessed the final outcomes based on creativity, communication clarity, and spatial articulation.

Tutor Involvement:

Tutors received a dedicated training session prior to the start of the semester to familiarize themselves with the MR platforms and understand their pedagogical roles. Throughout the project, they were responsible for guiding students not only in design development but also in using immersive technologies effectively as design mediums. Weekly staff meetings ensured consistency of feedback and shared reflection on the pedagogical impact of MR use.

This scaffolded design and delivery approach ensured that the MR experiment was not simply a technological overlay but was deeply embedded into the structure of the architectural design studio. It reflected the real-world dynamics of architectural practice—collaborative, iterative, and increasingly digital—while remaining grounded in educational best practices.

7.4.3 Data Collection Methods

A combination of quantitative and qualitative data was collected to assess the impact of MR on the participants' design processes. Following Chapter 4's methodology, data was gathered through:

- Pre-experiment and post-experiment questionnaires: These provided quantitative data on participants' confidence, creativity, communication, and competence before and after the experiment.
- Semi-structured interviews: Conducted midway and at the end of the semester, these interviews allowed participants to reflect on their experiences using MR. Interviews were transcribed and coded for thematic analysis, following Braun & Clarke's (2006) six-step approach to identify key themes related to design thinking, collaboration, and spatial understanding.
- Direct observation: While not intrusive, observational data was collected by shadowing students during design workshops. Tutors also contributed observational data by reflecting on how students engaged with the MR tools during the semester, in line with the discussion in Chapter 4 on the importance of non-intrusive observation (Robson, 2011).
- Weekly progress questionnaires: Participants were asked to fill out reflective questionnaires documenting their design processes, challenges, and breakthroughs. This qualitative data provided additional insights into how MR influenced their creative exploration and decision-making throughout the semester.

7.4.4 Limitations

Despite the positive outcomes of the MR experiment, several limitations were encountered that warrant critical reflection. Firstly, the high cost and limited availability of MR equipment constrained the number of students who could engage in immersive experiences simultaneously. While the rotation system ensured that all participants had

some hands-on time, the inconsistency in access may have affected the depth of engagement and skewed experiences between participants. This also limited opportunities for sustained iterative design in MR environments for all students, potentially influencing the uniformity of the results.

Secondly, technical issues such as intermittent headset tracking problems, software crashes, and unstable internet connectivity occasionally disrupted design sessions. Although these were managed quickly by technical support staff, such interruptions may have impacted the flow of learning and the overall user experience. These technical barriers highlight the importance of robust infrastructure and technical training in scaling MR integration into mainstream curricula.

Lastly, while a full 12-week semester offered more extended exposure than the shorter VR and AR workshops, many students reported that it was still not sufficient to fully master MR tools or explore their design potential to the fullest. The learning curve associated with immersive tools meant that a significant portion of the early phase was spent on technical acclimatization rather than deep conceptual development. This underscores the need for long-term integration of MR across multiple modules, rather than confining it to a single semester-long experiment.

Collectively, these limitations suggest that while MR holds transformative potential, its successful integration into architectural education requires not only investment in equipment and infrastructure but also long-term pedagogical planning and iterative scaffolding. Future research should explore longitudinal studies, enhanced support

systems, and curriculum-wide adoption strategies to mitigate these challenges and maximize the educational value of MR.

7.5 Data Collection Methods

Data collection in the Mixed Reality (MR) experiment was designed to provide a comprehensive understanding of the impact of MR on creativity, communication, confidence, and competence in architectural education. To achieve this, a multi-method approach was adopted, combining both quantitative and qualitative methods to ensure that data collected was robust, reliable, and addressed the research questions comprehensively. As outlined in Chapter 4, the use of mixed methods allows for the triangulation of data, providing a fuller picture of the research findings (Johnson & Onwuegbuzie, 2007).

7.5.1 Surveys and Questionnaires

The primary method of quantitative data collection was through pre-experiment and post-experiment surveys. These surveys were designed to measure participants' self-reported creativity, communication, confidence, and competence before and after engaging with the MR tools.

- Pre-experiment surveys: These surveys were administered before the introduction of MR to establish baseline data on participants' familiarity with immersive technologies, particularly in design contexts. Participants were asked to rate their skills in spatial reasoning, design problem-solving, communication, and overall confidence in using digital tools.

- Post-experiment surveys: After completing the semester-long MR workshop, participants were surveyed again to measure changes in these key areas. The use of Likert-scale questions allowed for statistical analysis of changes in creativity, communication, confidence, and competence levels, as explored in Chapter 4.6 Data Analysis. The surveys also included open-ended questions to gather qualitative insights into participants' experiences and reflections on using MR in design education. This provided a balance between numerical data and more nuanced, subjective responses.

The survey questions were informed by the literature on immersive technologies in education, particularly the frameworks presented in Chapter 3 on the role of immersive technologies in enhancing engagement, spatial reasoning, and collaborative learning (Abdelhameed, 2011; Angulo et al., 2015).

7.5.2 Semi-Structured Interviews

To complement the quantitative data, semi-structured interviews were conducted with both students and tutors throughout the experiment. The thematic analysis method, as outlined by Braun and Clarke (2006), was used to identify key themes from the qualitative data, focusing on participants' experiences with MR tools.

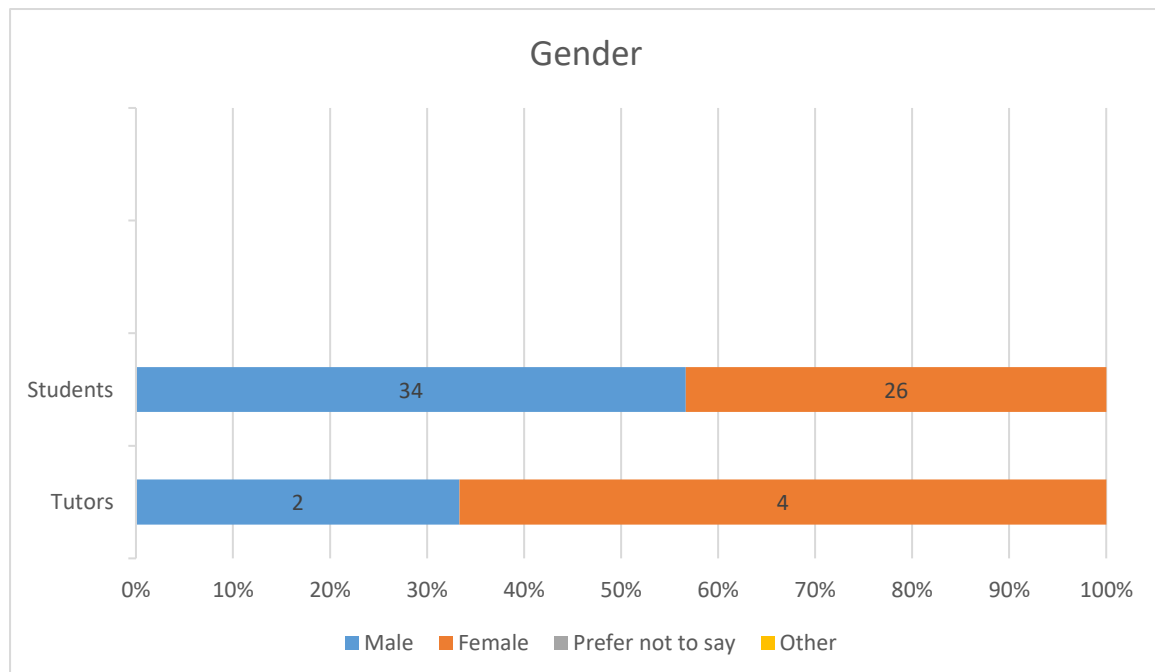
- Student interviews: Conducted at the midpoint and end of the semester, these interviews focused on understanding how MR influenced students' design thinking and spatial understanding. Questions probed how participants used MR in their design process, whether they felt more confident presenting their designs

in an MR setting, and how MR impacted their ability to collaborate and communicate ideas.

- Tutor interviews: Tutors were interviewed to gain insights into how MR supported their teaching methods, particularly in providing feedback and facilitating student understanding of complex spatial and material concepts. Tutors were asked to compare MR's effectiveness with more traditional tools such as CAD or physical models, building on themes discussed in Chapter 3, including the limitations of traditional design tools and the potential for immersive technologies to address these gaps (Birt et al., 2018; Dorta et al., 2016).

7.6 Pre experiment Results Analysis for MR (Mixed Reality) Semester Project

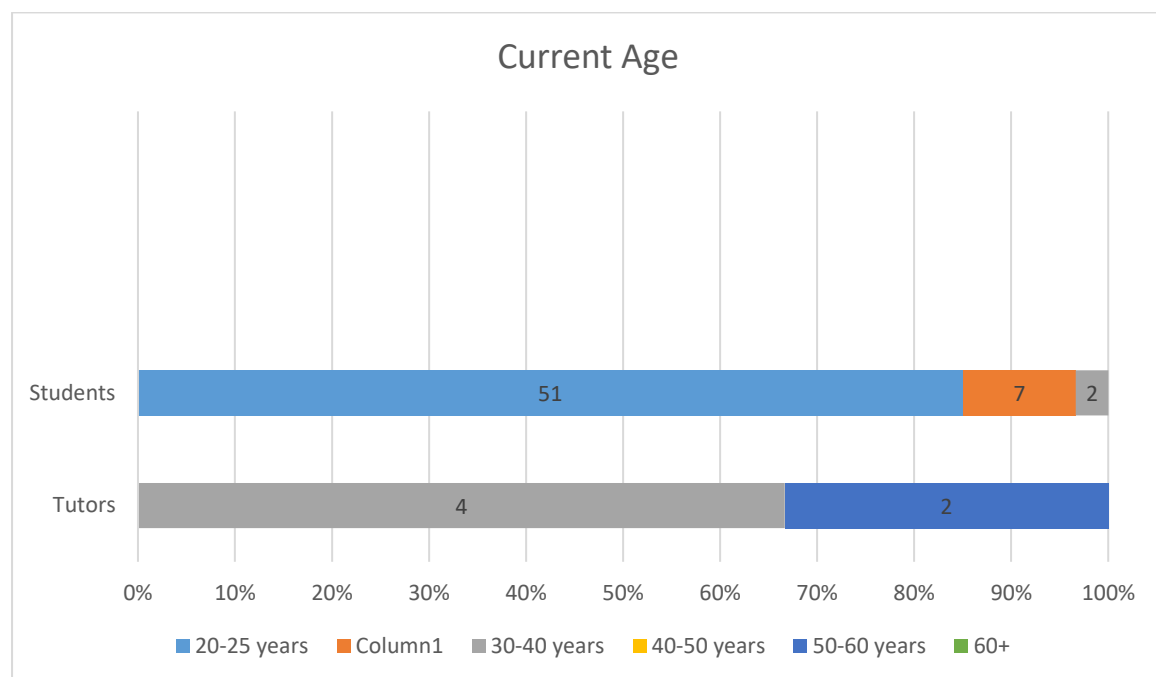
Figure 7.6.1 Gender Distribution



Source: Compiled by the author, (2024)

Analysis: The gender distribution shows a higher proportion of female tutors and a relatively balanced gender representation among students. This diversity is essential for ensuring a broad range of perspectives in the MR workshops, contributing to a more inclusive and comprehensive learning environment.

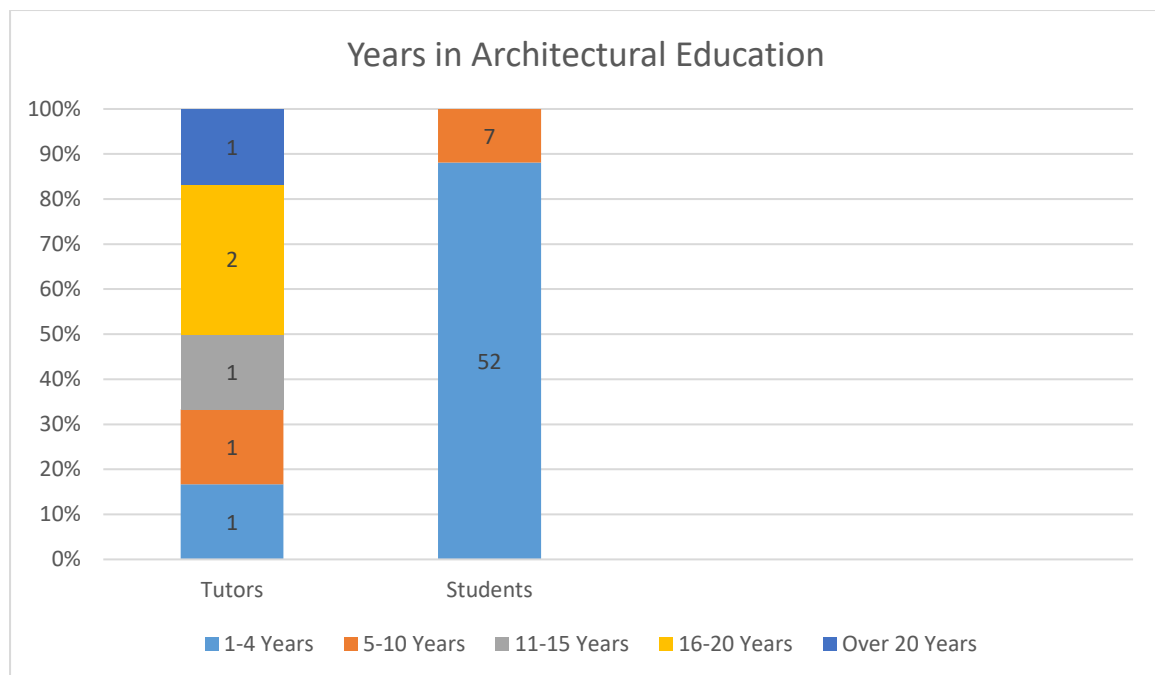
Figure 7.6.2 The information regarding the age of the respondents.



Source: Compiled by the author, (2024)

Analysis: The age distribution highlights that students are primarily in their early twenties, typical of undergraduate cohorts, while tutors are mid-career professionals. This mix can create a dynamic educational experience, combining youthful creativity with experienced guidance.

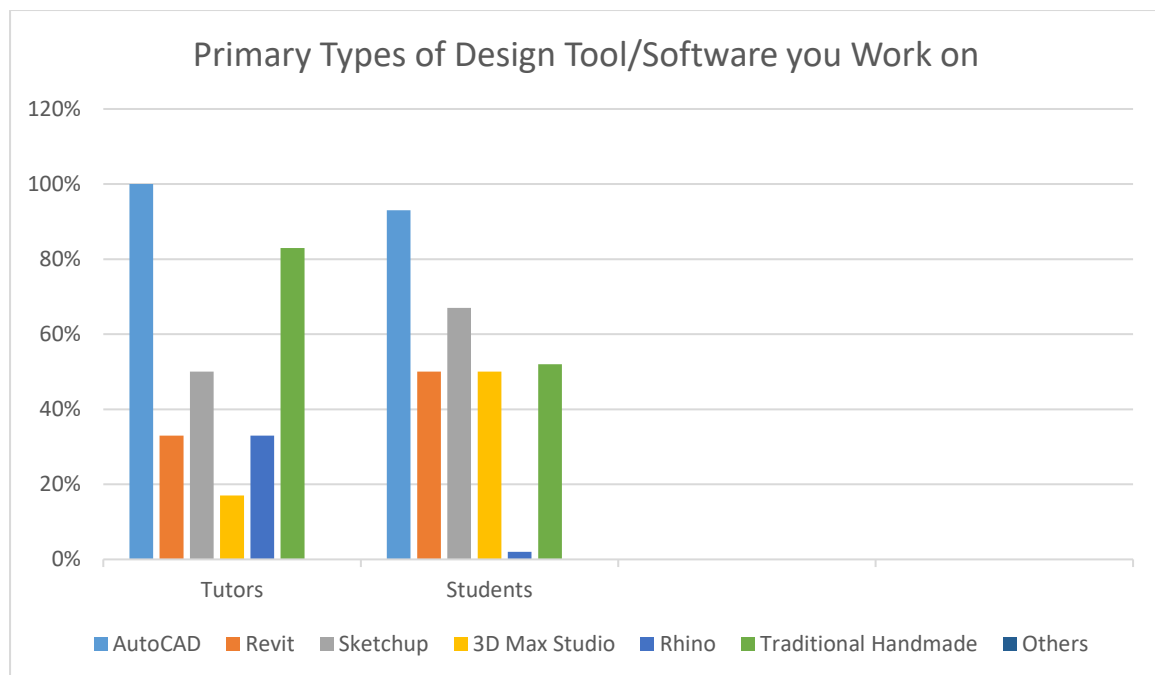
Figure 7.6.3 Showing information regarding the years in education of the respondents.



Source: Compiled by the author, (2024)

Analysis: Most students are early in their architectural education journey, while tutors have substantial experience. This dynamic allows students to benefit from the extensive knowledge and mentorship of their tutors, enhancing their learning experience.

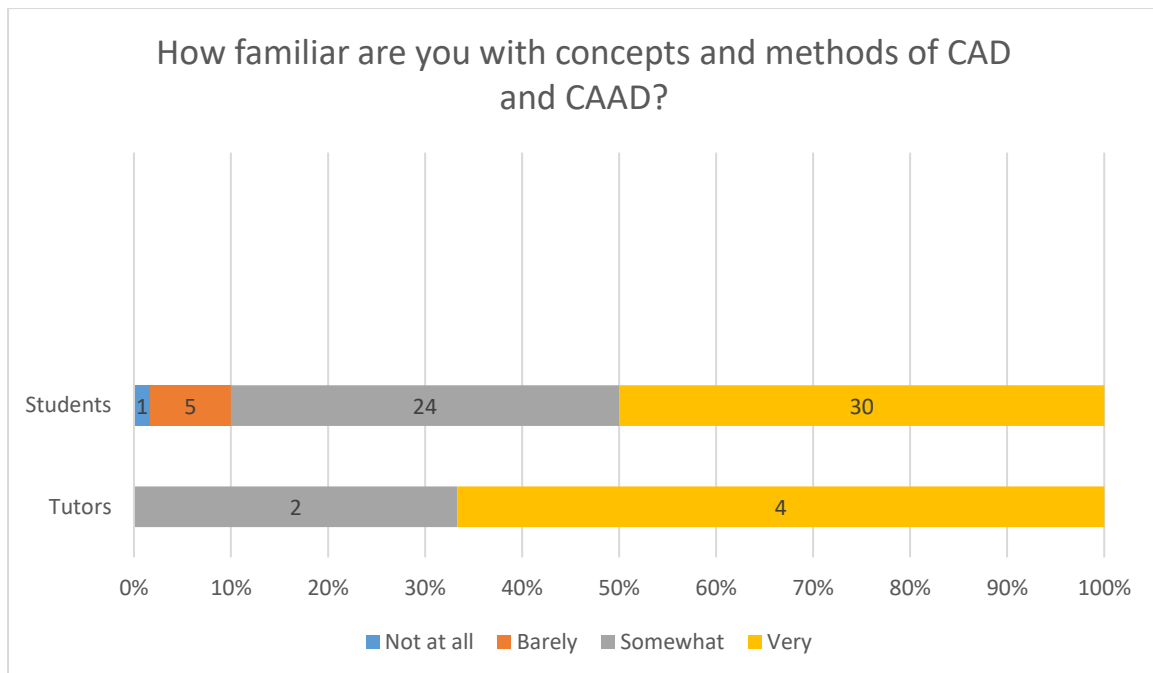
Figure 7.6.4 Primary Types of Design Tools/Software Used



Source: Compiled by the author, (2024)

Analysis: The data shows a strong reliance on traditional and widely-used design tools among both tutors and students. This familiarity with digital and manual design tools suggests readiness for integrating MR into their workflows to enhance their design capabilities.

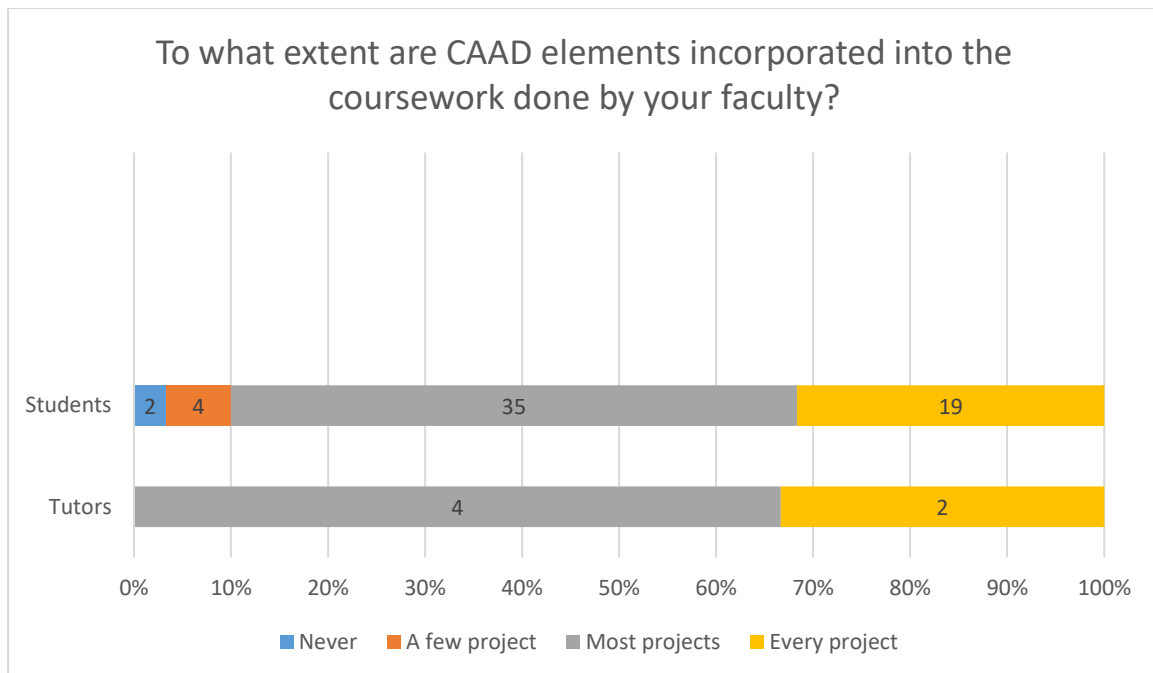
Figure 7.6.5 Familiarity with CAD and CAAD Concepts and Methods



Source: Compiled by the author, (2024)

Analysis: Both tutors and students have a considerable familiarity with CAD and CAAD concepts. This proficiency indicates that participants are well-prepared to engage with MR technologies, which build on their existing digital design knowledge.

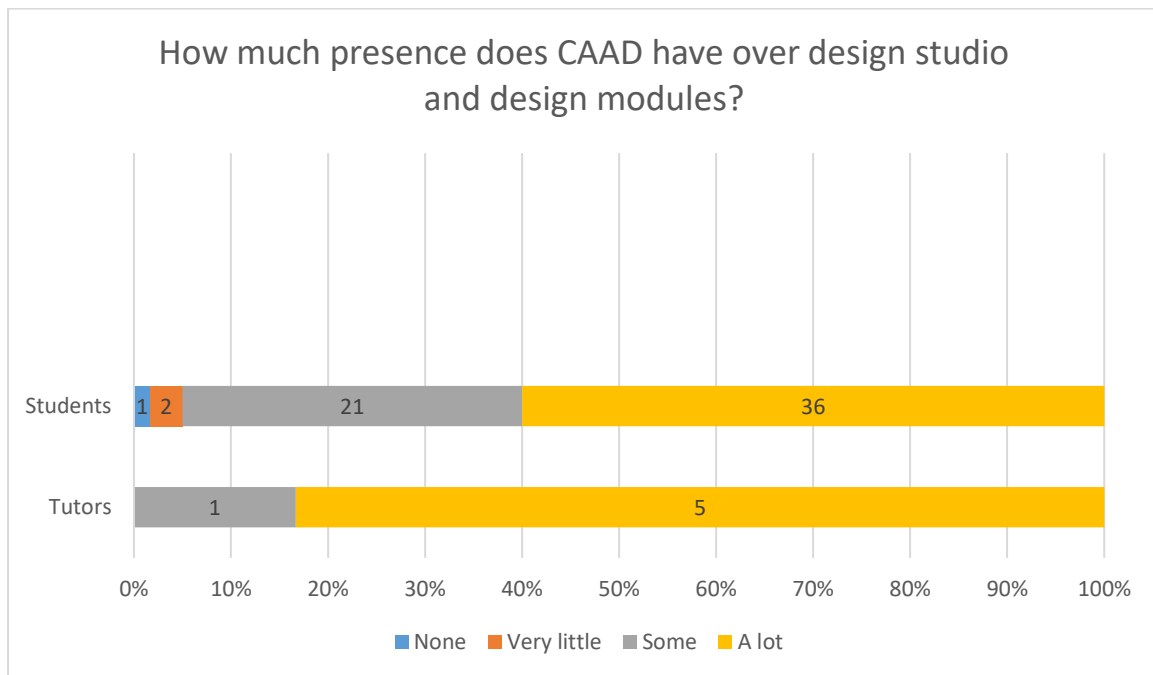
Figure 7.6.6 Incorporation of CAAD Elements into Coursework



Source: Compiled by the author, (2024)

Analysis: The frequent use of CAAD elements in coursework highlights the progressive adoption of digital technologies in architectural education. This integration provides a solid foundation for introducing MR, ensuring students are already accustomed to digital design tools.

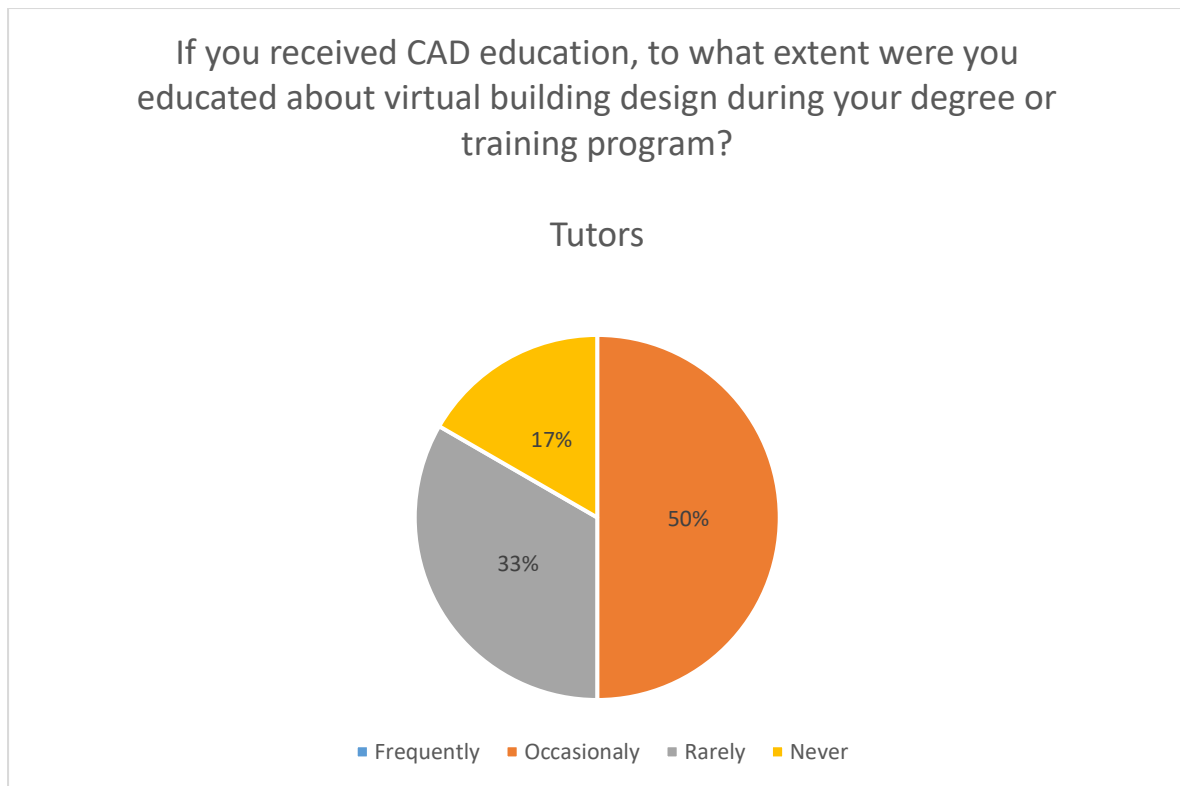
Figure 7.6.7 Presence of CAAD in Design Studios and Modules



Source: Compiled by the author, (2024)

Analysis: The established presence of CAAD in design studios indicates a readiness to enhance these practices with MR technologies. The balance between 'some' and 'a lot' suggests significant incorporation of digital tools, which can be further enriched with MR experiences.

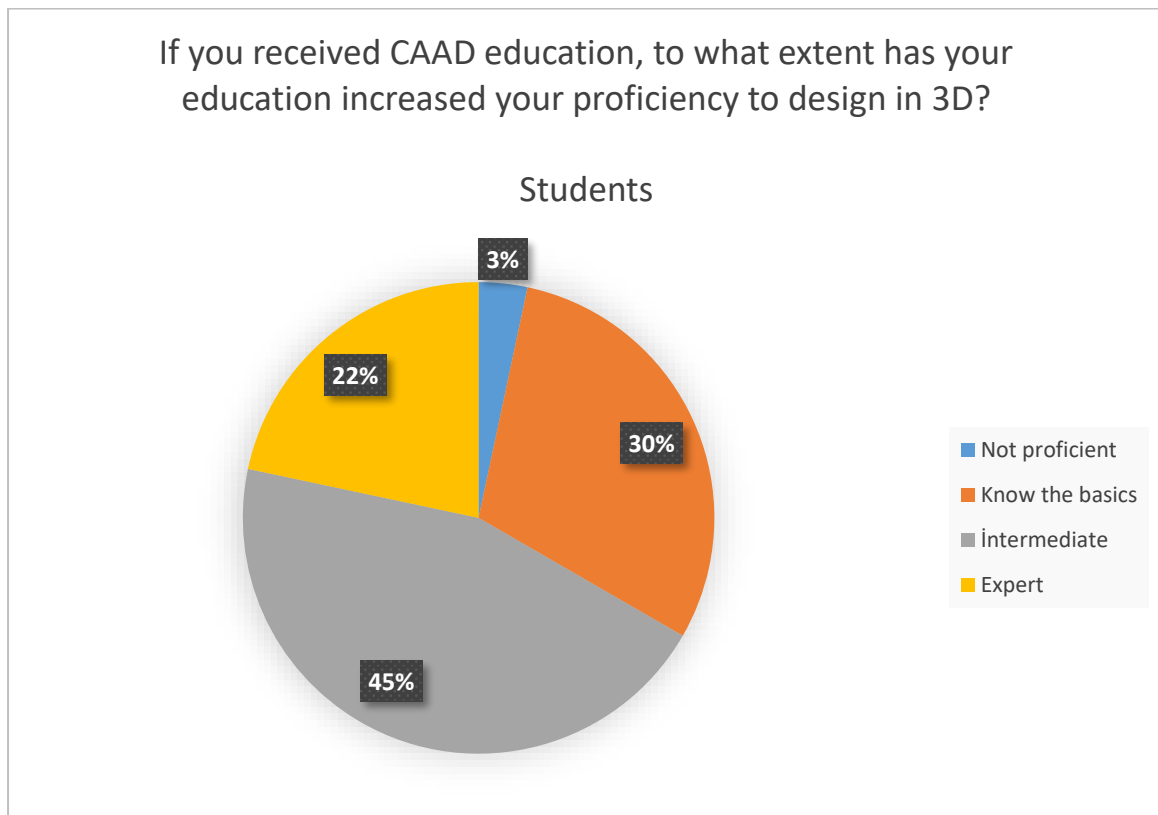
Figure 7.6.8 Education on Virtual Building Design (Tutors)



Source: Compiled by the author, (2024)

Analysis: This variation in VR education among tutors highlights the need for standardized training to ensure consistent competency in MR. Frequent to occasional exposure suggests a foundation upon which more immersive and comprehensive MR training can be built.

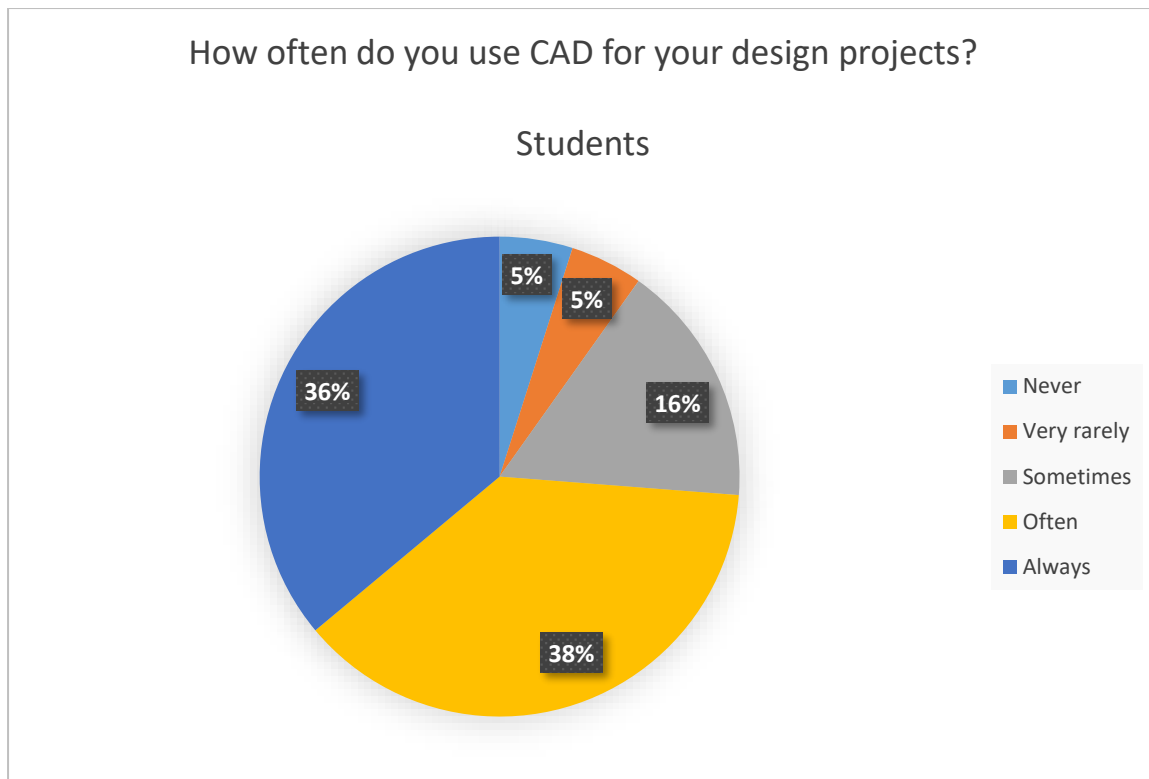
Figure 7.6.9 Proficiency in 3D Design Post-CAAD Education (Students)



Source: Compiled by the author, (2024)

Analysis: The high proficiency in 3D design among students indicates they are well-prepared to leverage MR for more advanced and immersive design projects. This proficiency suggests a strong potential for MR to further enhance their design capabilities.

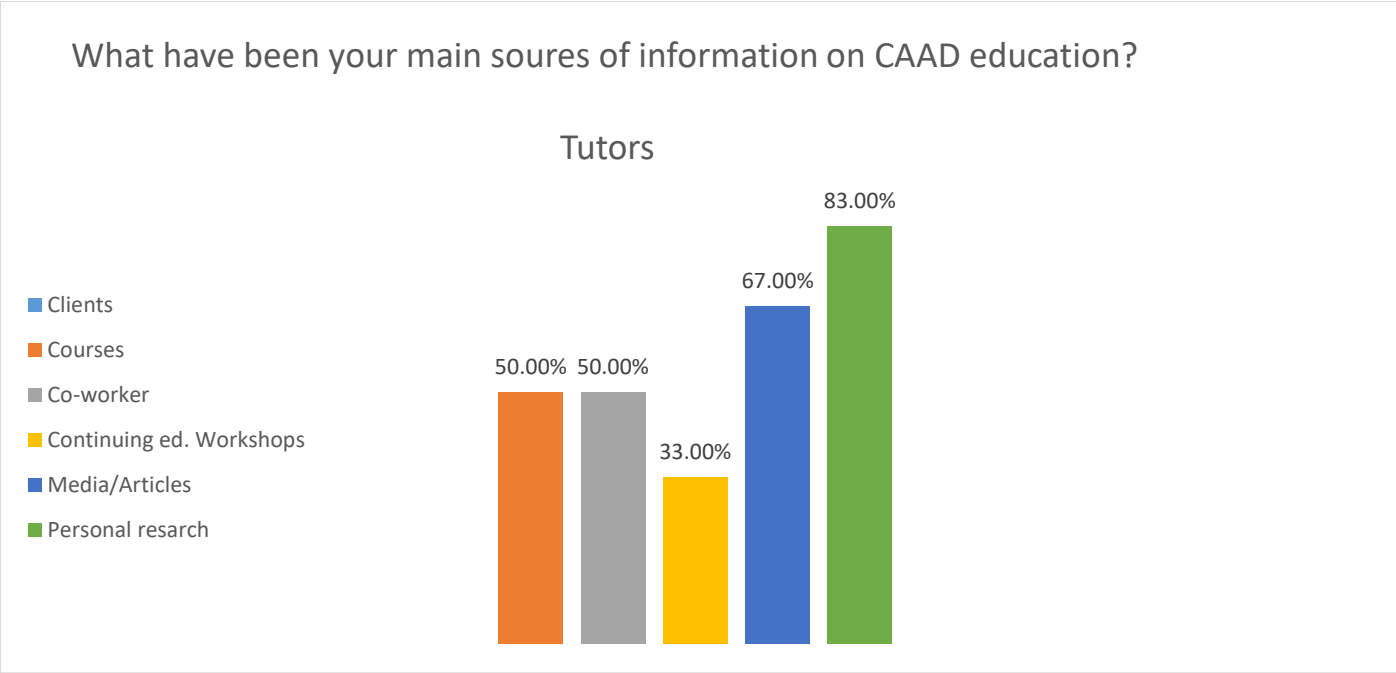
Figure 7.6.10 Frequency of CAD Use in Design Projects (Students)



Source: Compiled by the author, (2024)

Analysis: Regular use of CAD demonstrates the integral role of digital tools in students' design processes, paving the way for MR adoption. The frequent use underscores the importance of integrating MR to further enrich their design experience.

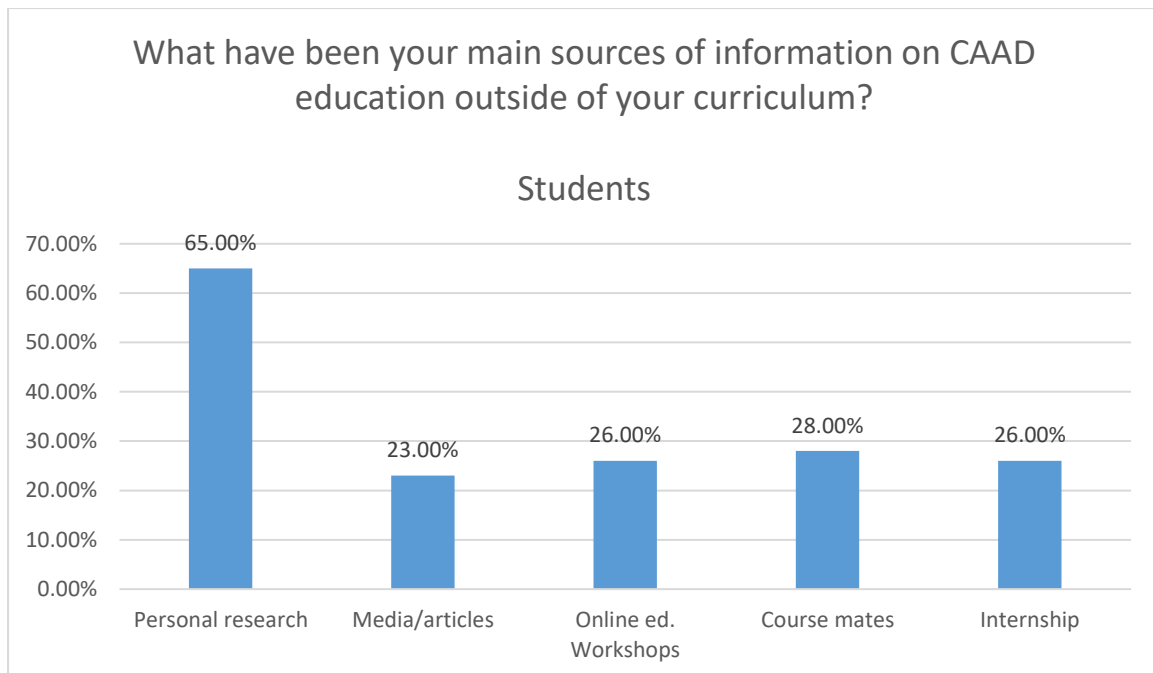
Figure 7.6.11 Main Sources of Information on CAAD Education (Tutors)



Source: Compiled by the author, (2024)

Analysis: The diverse sources of CAAD information highlight the proactive learning approaches of both students and tutors, which can be beneficial in integrating MR education. Personal research and peer collaboration are significant, suggesting a strong culture of self-directed learning.

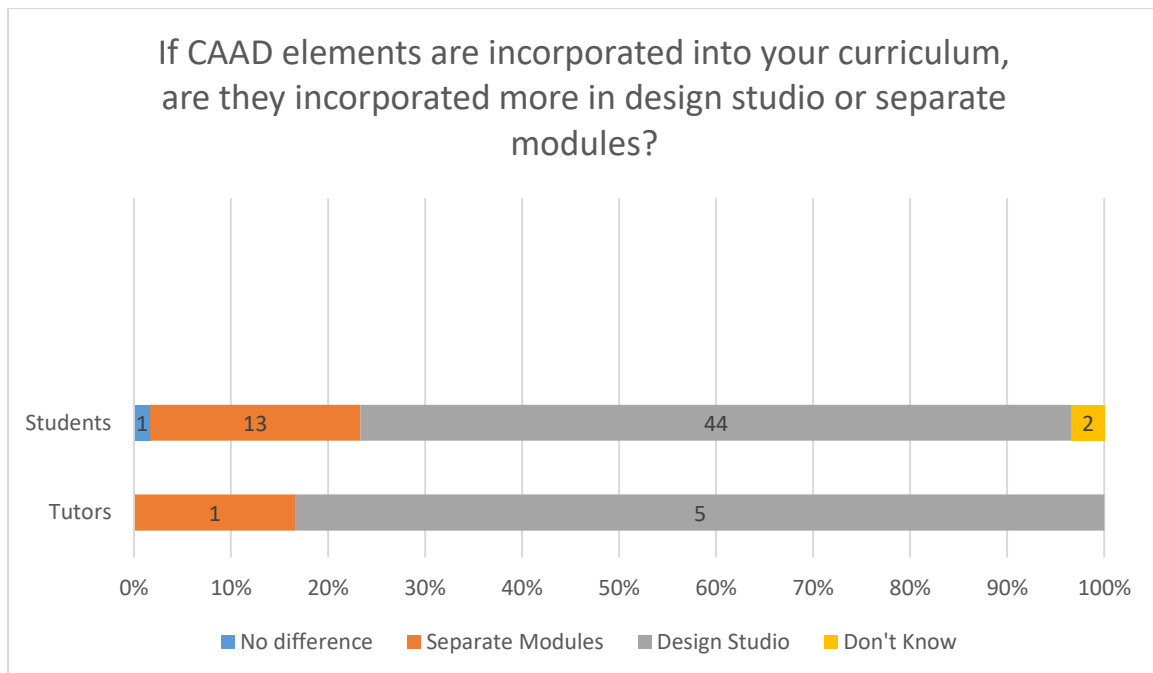
Figure 7.6.12 Main Sources of Information on CAAD Education (Students)



Source: Compiled by the author, (2024)

Analysis: The diverse sources of CAAD information highlight the proactive learning approaches of both students and tutors, which can be beneficial in integrating MR education. Personal research and peer collaboration are significant, suggesting a strong culture of self-directed learning.

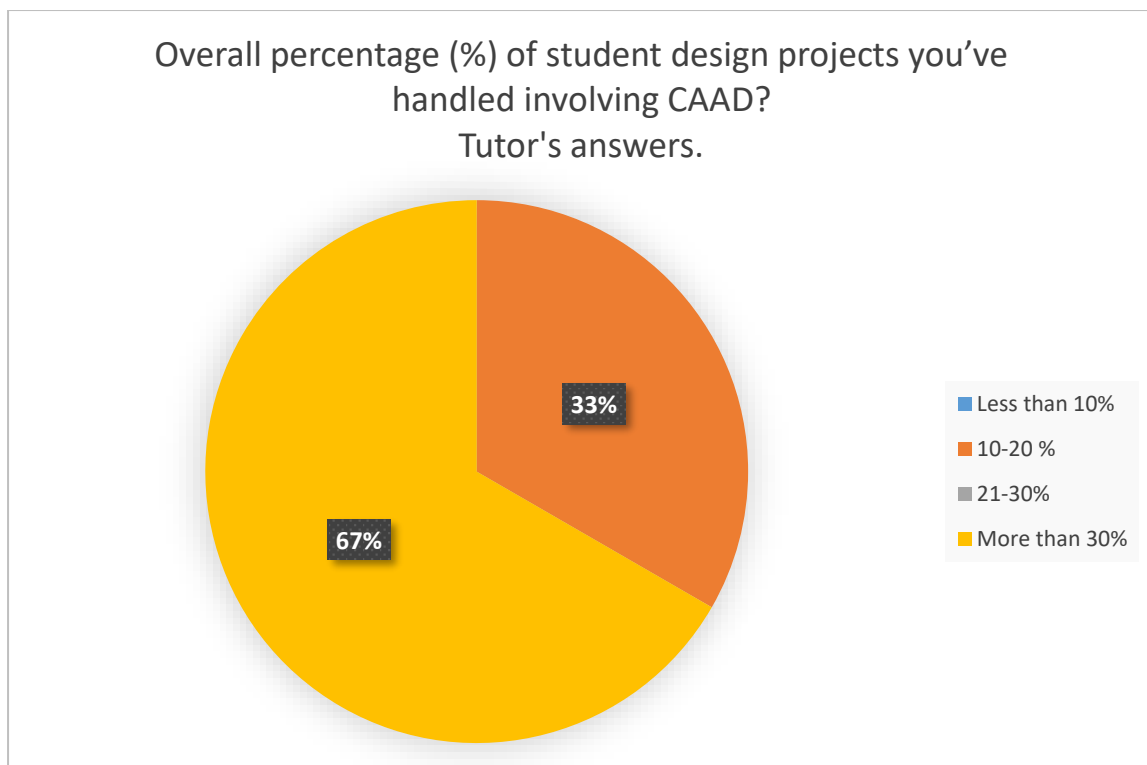
Figure 7.6.13 Integration of CAAD in Curriculum



Source: Compiled by the author, (2024)

Analysis: Flexible integration of CAAD indicates that MR can be similarly incorporated across different aspects of the curriculum to enhance learning. The varied responses suggest that both design studio and separate modules can effectively support digital tool integration.

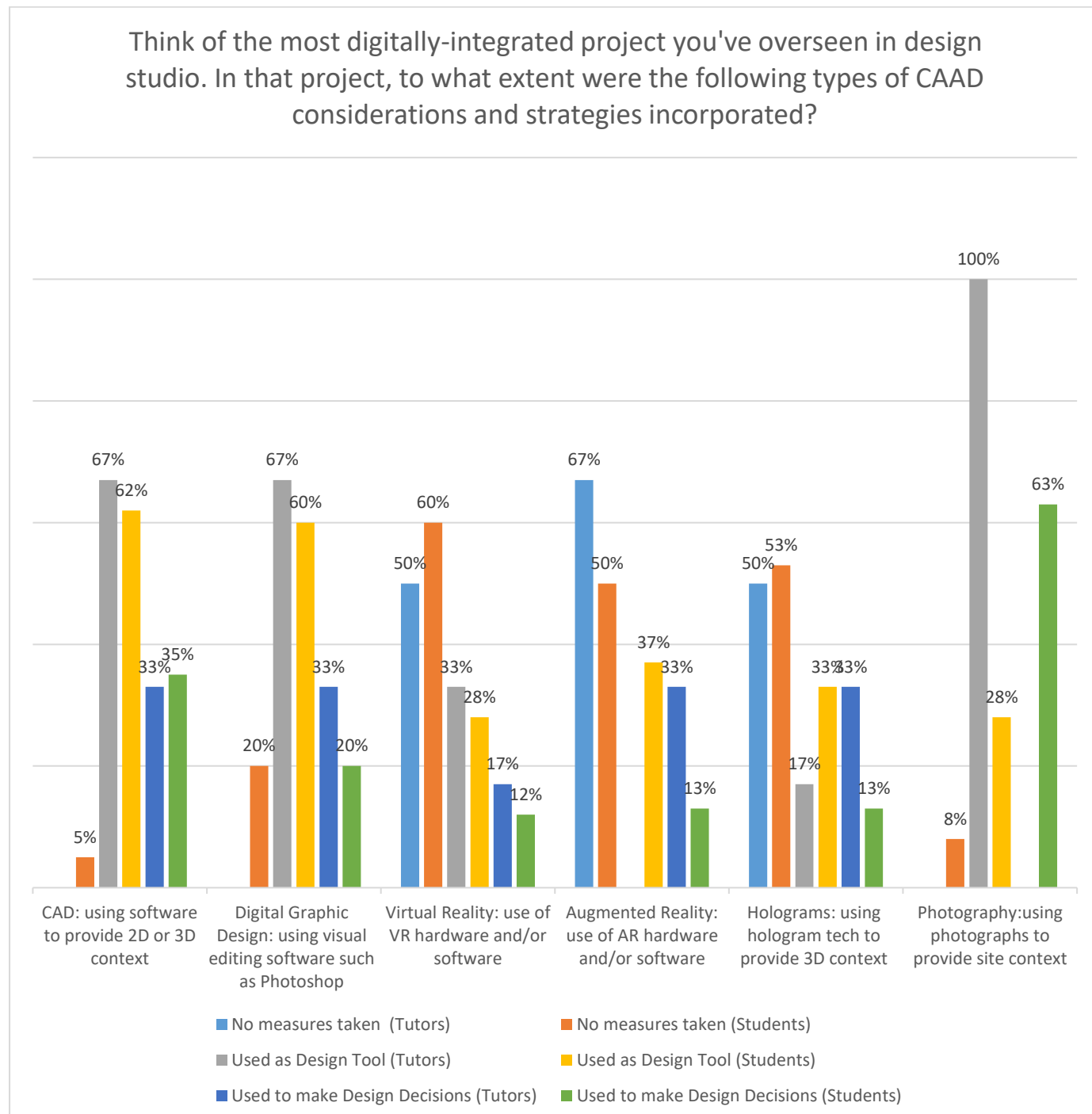
Figure 7.6.14 Percentage of Design Projects Involving CAAD (Tutors)



Source: Compiled by the author, (2024)

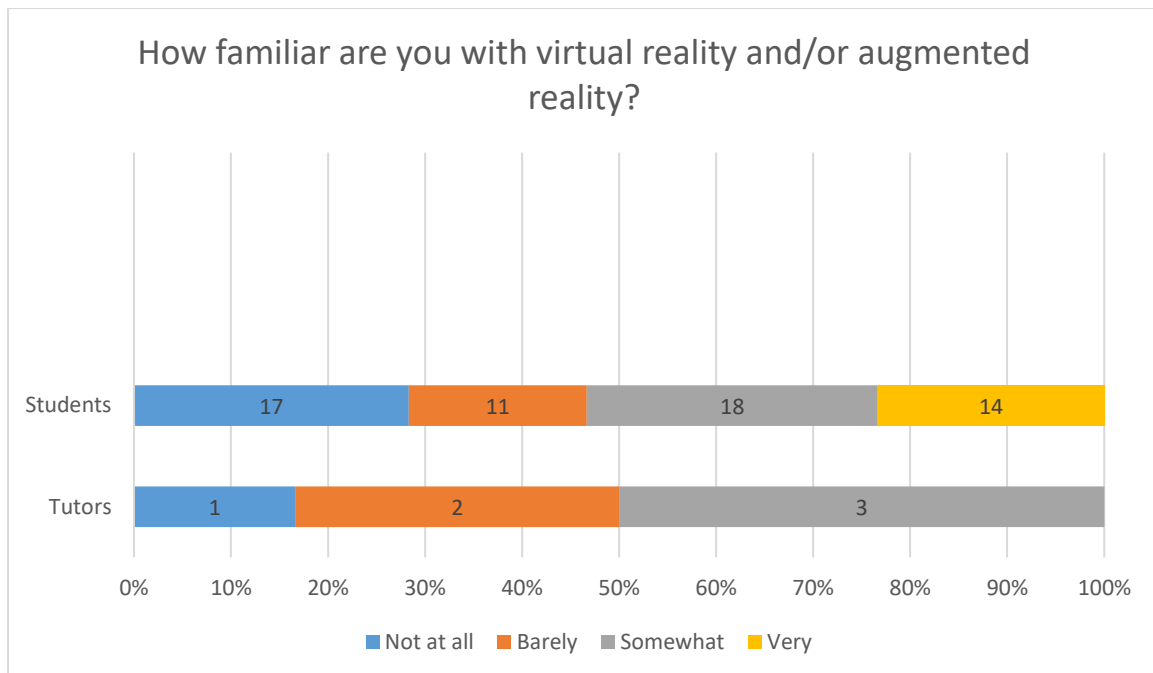
Analysis: The substantial integration of CAAD in design projects underscores the readiness for further incorporating MR technologies to enhance these projects. The balanced distribution indicates varying levels of CAAD engagement, all of which can benefit from MR integration.

Figure 7.6.15 Incorporation level of various CAAD considerations and strategies to design projects



Source: Compiled by the author, (2024)

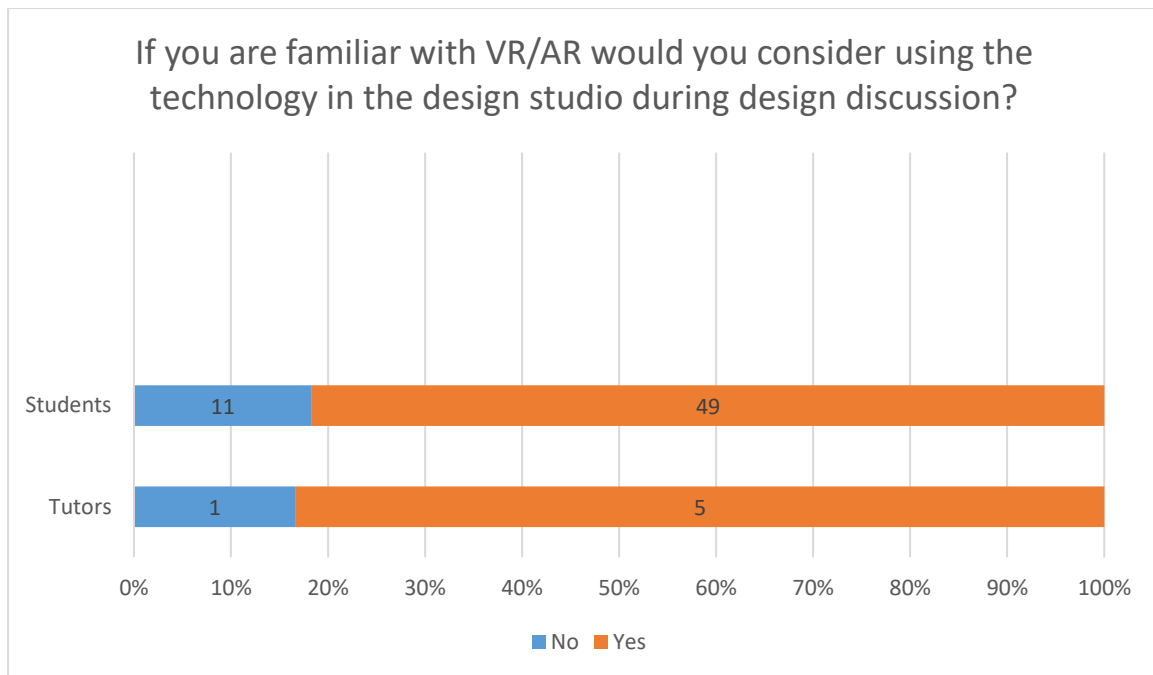
Figure 7.6.16 Familiarity with VR/AR



Source: Compiled by the author, (2024)

Analysis: General familiarity with VR/AR indicates a baseline knowledge that can be built upon with more immersive and hands-on experiences in the workshops. The higher familiarity among students suggests a readiness to explore VR/AR further.

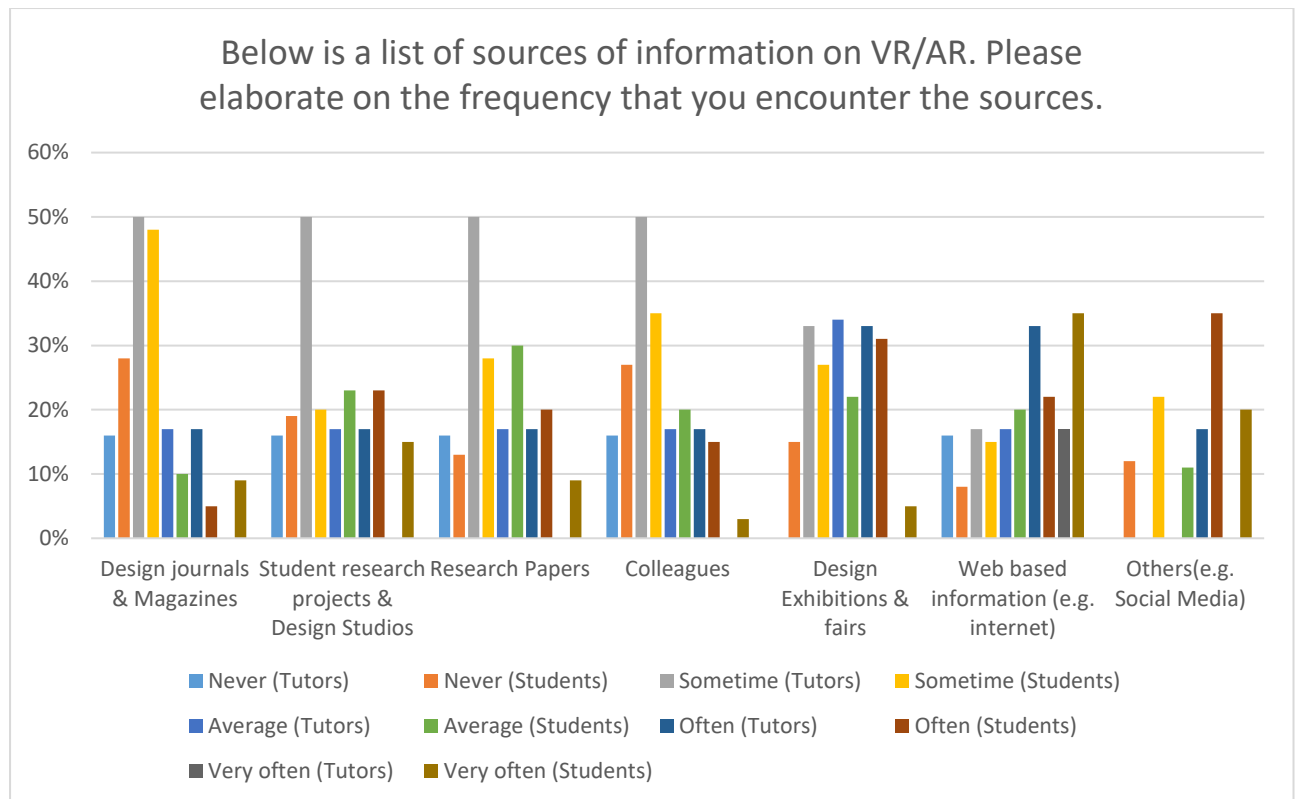
Figure 7.6.17 Willingness to Use VR/AR in Design Studios



Source: Compiled by the author, (2024)

Analysis: The strong interest in using VR/AR highlights the enthusiasm and openness to adopting new technologies in architectural education. This willingness provides a solid foundation for integrating Analysis of MR Experiment Pre-Experiment Questionnaire Results (Participants taking part in the experiment for the first time)

Figure 7.6.18 Sources of Information on VR/AR



Source: Compiled by the author, (2024)

Analysis: The chart in Figure 7.6.18 highlights the variety of channels through which students and tutors access information about VR/AR. While both groups rely on multiple sources, notable differences in frequency and preferences are evident.

Tutors most frequently reported encountering VR/AR information through design journals & magazines, colleagues, and design exhibitions & fairs—all of which suggest a preference for formal and peer-based professional learning environments. In contrast, students show a stronger inclination toward web-based information and social media, as reflected by the highest proportions of “often” and “very often” responses in those categories.

When compared to the data in Chapter 5, a clear divergence in learning behaviours emerges. Tutors tend to engage in traditional, academically oriented channels, whereas students lean toward informal, on-demand digital platforms. Interestingly, tutors also scored higher in accessing knowledge through colleagues and research papers, showing a more collaborative and scholarly knowledge network.

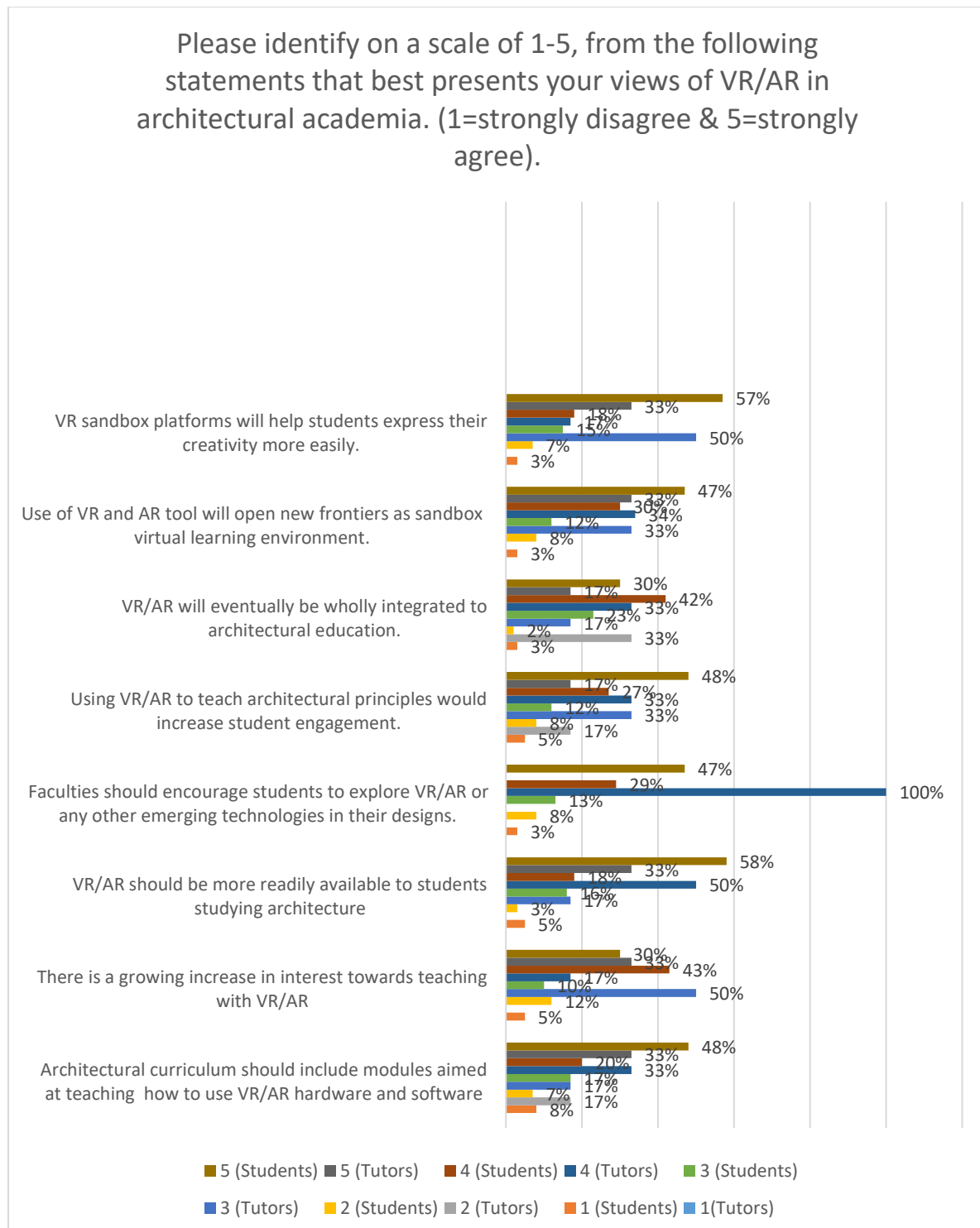
This divergence may reflect generational differences, but also illustrates a possible disconnect in the flow of information between educators and learners. While students demonstrate an eagerness to explore content through online platforms, the lack of peer collaboration among students, particularly in design studios and project-based learning, suggests a missed opportunity for shared knowledge development. This aligns with the earlier observations in Chapter 5, where students were found to be less reliant on peer exchanges than tutors.

In light of this, a reconsideration of how VR/AR education is supported and delivered is necessary. These findings highlight the need to:

- Bridge the gap between formal academic resources and more informal student-preferred platforms.
- Encourage structured peer-based information sharing among students.
- Provide unified, curated access points that balance scholarly rigor with accessibility.

Such efforts would not only improve information flow but also foster more collaborative, integrated learning cultures around immersive technologies.

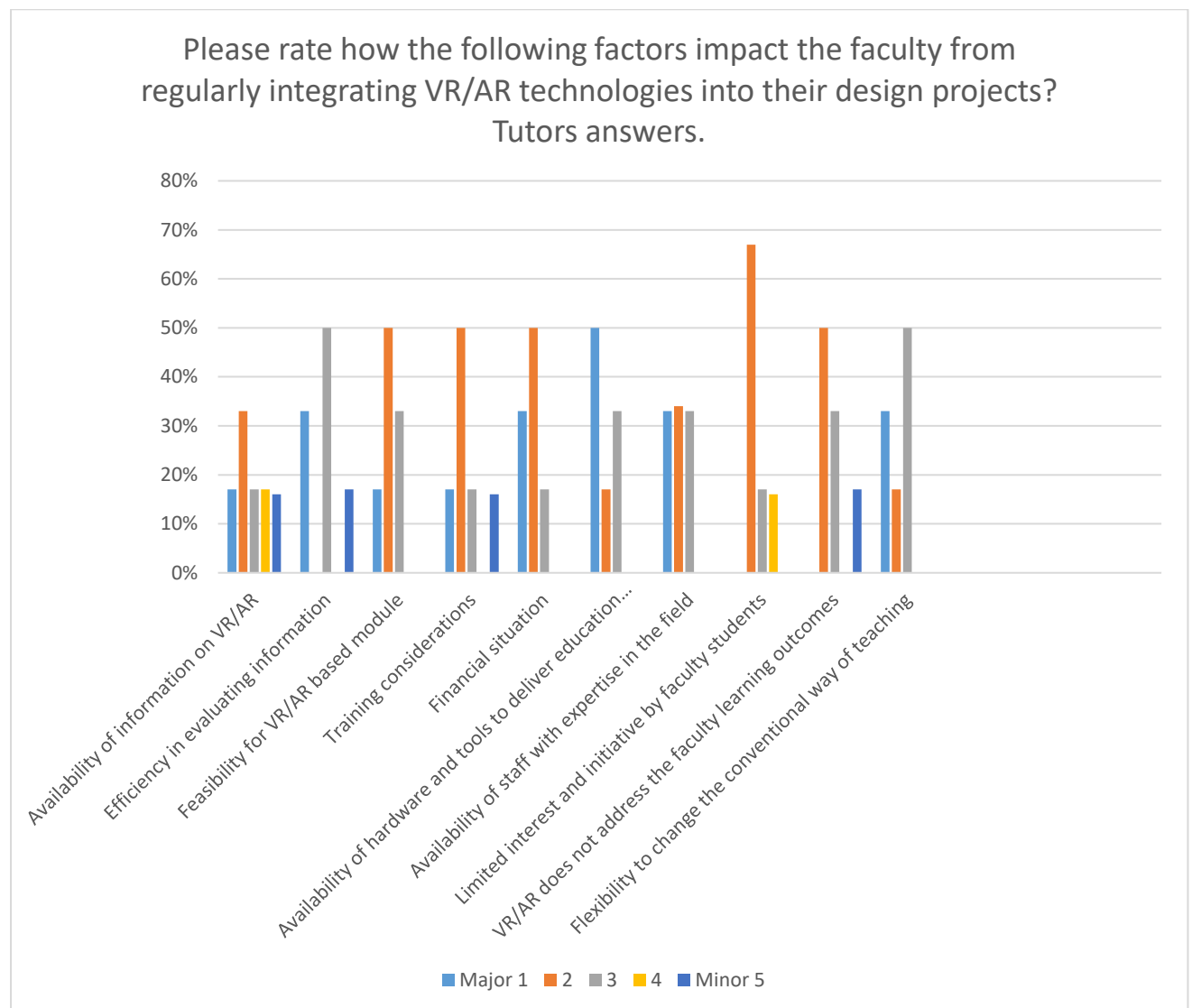
Figure 7.6.19 Views on VR/AR in Architectural Academia



Source: Compiled by the author, (2024)

Analysis: There is strong agreement among both tutors and students on the benefits of VR/AR in architectural education. High levels of agreement suggest that VR/AR is seen as a valuable tool that can enhance student engagement and open new frontiers in architectural education.

Figure 7.6.20 Hindrances to Integrating VR/AR Technologies



Source: Compiled by the author, (2024)

Analysis: Figure 7.6.20 presents the perspectives of tutors regarding the factors hindering the regular integration of VR/AR technologies into architectural design education. Several noteworthy insights emerge, especially when compared with the broader faculty responses analyzed in Figure 5.5.3.21 in Chapter 5.

The top-rated hindrance is “Limited interest and initiative by faculty/students,” rated as a major barrier (2) by over 70% of respondents. This marks a notable shift from Figure 5.5.3.21, where “Lack of hardware and tools” and “Difficulty evaluating information” were more prominent. This suggests that while infrastructural challenges remain relevant, personal motivation and institutional culture now represent the primary barriers from the tutors’ point of view.

Furthermore, Training Considerations and Availability of staff with expertise in the field both score highly, echoing earlier findings from Chapter 5 but now with greater emphasis. This shift indicates a growing awareness among tutors of internal capacity-building needs over purely external or technical constraints. The emphasis on “Feasibility for VR/AR based module” as a significant barrier further supports this, suggesting a concern not just with the availability of resources but with the adaptability of current curricula.

When compared to student or broader faculty responses, tutors appear more focused on pedagogical and systemic challenges, including:

- Low student initiative
- Flexibility to change conventional teaching methods
- Concerns about alignment with learning outcomes

These concerns are indicative of a cautious or reflective stance from educators, which may stem from the perceived pedagogical complexity of immersive technologies, rather than a rejection of their potential. This comparative insight underscores the difference in expectations and perceived obstacles between broader faculty (Chapter 5) and tutors specifically (Chapter 7). While technical and financial limitations dominate student-facing data, tutor responses reflect pedagogical uncertainty, institutional rigidity, and engagement challenges.

To support successful integration, it is therefore essential to:

- Foster bottom-up engagement by involving tutors in the co-creation of immersive modules
- Deliver targeted training and mentorship programmes focused on immersive teaching practices
- Clarify the alignment between VR/AR capabilities and curricular learning outcomes

This layered approach will help address both systemic and motivational barriers, creating a more supportive environment for the adoption of immersive technologies in architectural pedagogy.

7.7 Mid-Experiment Results Analysis for MR (Mixed Reality) Semester Project (Week's Session Answers)

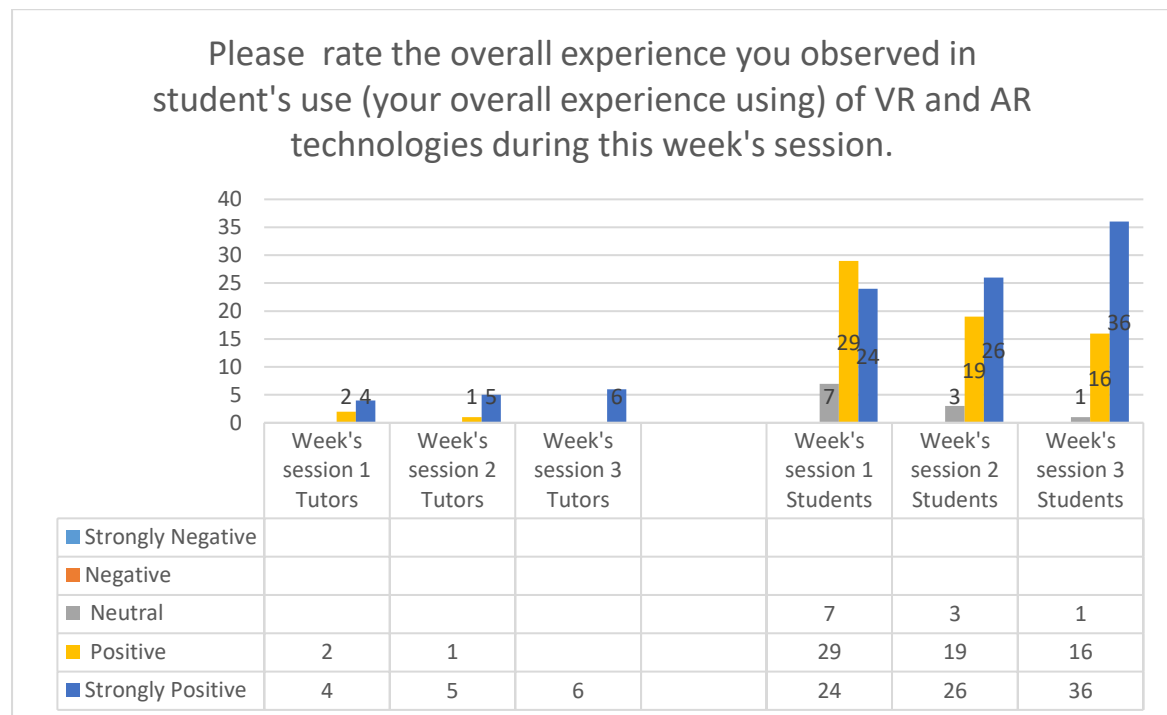
To capture the longitudinal aspects of learning with MR, participants were asked to complete weekly progress reports and reflections. These reports provided valuable insight into how students' skills in creativity, communication, confidence, and competence evolved over the course of the semester.

- Weekly reflections: Students reflected on their experiences using MR, detailing specific challenges they encountered, how they overcame these challenges, and how their designs evolved through iterative feedback using MR. These reflections were also used to gauge participants' growing familiarity and comfort with using MR tools, tracking changes in their confidence and competence as the semester progressed.

These reports were integral in identifying long-term patterns in how MR impacted students' learning trajectories, providing data that extended beyond the single-point snapshots obtained from the surveys and interviews. This method aligns with the suggestions in the literature, particularly those by Radi et al. (2021), who emphasize the

importance of longitudinal studies in understanding the sustained impact of immersive technologies on student learning.

Figure 7.7.1 Overall Experience Using VR and AR Technologies



Source: Compiled by the author, (2024)

Analysis: The data presented in Figure 7.7.1 illustrates a clear and progressive increase in positive perceptions of VR and AR technologies among both tutors and students over the three-week period. Among tutors, responses evolved from four "Strongly Positive" ratings in Week 1 to a unanimous six "Strongly Positive" ratings by Week 3, suggesting a steady increase in familiarity, comfort, and appreciation for the immersive tools. Students initially exhibited a more varied distribution, with 24 "Strongly Positive" and 29 "Positive" responses in Week 1, accompanied by seven neutral ratings. However, by Week 3, this shifted markedly to 36 "Strongly Positive" and only one neutral rating, with no negative responses reported throughout the study. This upward trend in both cohorts implies that continued exposure to immersive technologies contributes to

enhanced overall user experience and acceptance. Notably, the diminishing number of neutral responses—particularly among students—indicates a reduction in uncertainty or hesitation over time. The data thus supports the conclusion that both students and tutors increasingly valued the role of VR and AR in architectural education, and that familiarity and sustained use played a key role in improving engagement and satisfaction.

Statistical Analysis:

The data in Figure 7.7.1 reveals a compelling trajectory of growing confidence and satisfaction in the use of immersive technologies during the Mixed Reality (MR) workshop, as perceived by both students and tutors. Over the span of three weeks, participants showed a marked shift from mixed sentiments toward almost universal positivity in their evaluation of the tools.

For students, the progression is particularly striking. In Week 1, while 24 respondents selected *Strongly Positive* and 29 selected *Positive*, a significant portion (7) remained neutral, likely reflecting initial uncertainty or unfamiliarity with the technology. However, by Week 3, these hesitations had largely dissolved: 36 students rated the session *Strongly Positive*, 16 as *Positive*, and only 1 remained neutral. No negative ratings were recorded at any stage, pointing to the absence of technological rejection or dissatisfaction.

Tutors similarly reported steady improvement. Initially, 4 of the 6 tutors rated the first week as *Strongly Positive*, increasing to 5 in Week 2, and all 6 in Week 3. This gradual but complete movement toward maximum positivity suggests that even experienced educators benefited from continuous exposure, gradually aligning their instructional practices with the affordances of MR. These shifts are not only numerically evident but statistically reinforced. Wilcoxon signed-rank tests confirm highly significant improvements across weeks ($p = 1.000$, $p < 0.001$), indicating a perfect positive trend in both groups' evaluations. While no statistically significant differences emerged between students and tutors week-by-week (all $p > 0.05$), Week 2 and Week 3 values ($p = 0.051$ and $p = 0.059$, respectively) approached significance—suggesting that students were steadily catching up to tutors in confidence and comfort levels.

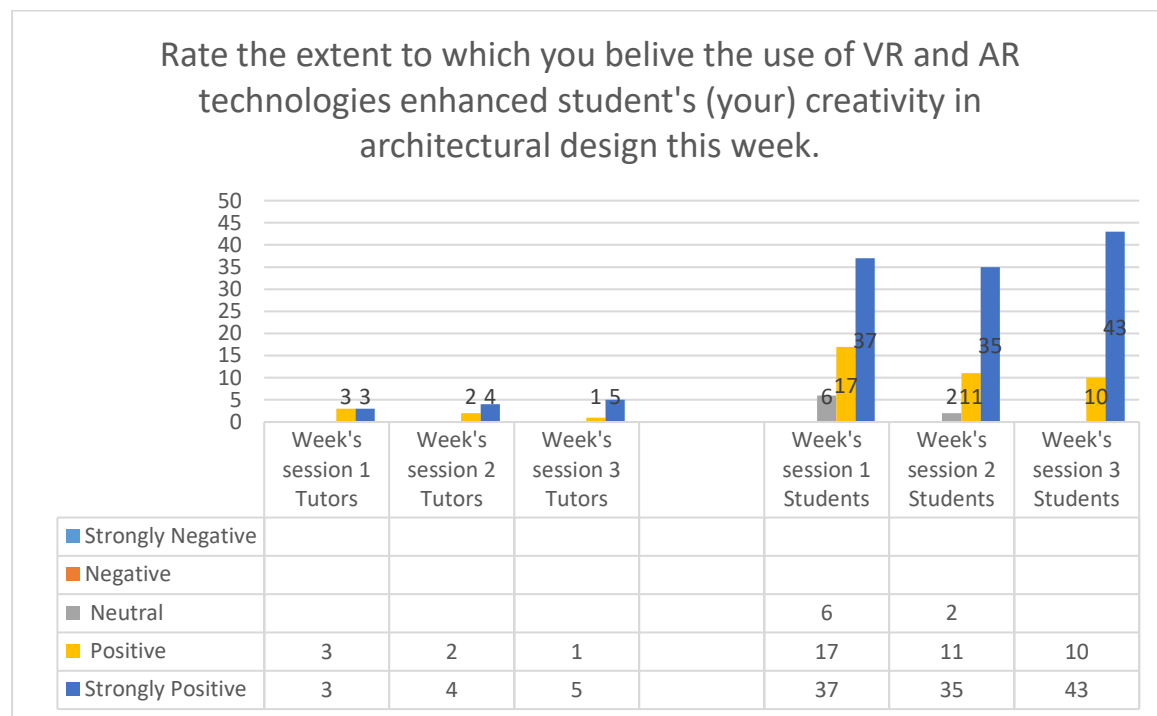
The convergence pattern is notable. In Week 1, a modest gap separated tutor and student perceptions (4.67 vs. 4.28). By Week 3, this gap narrowed (5.00 vs. 4.66), showing not only improvement but a growing shared understanding and enthusiasm between cohorts. This trajectory reflects a key theme discussed in Chapter 3 of the thesis: immersive technologies act as cognitive equalizers, reducing hierarchies of expertise and encouraging more equitable design dialogues (Resnick, 2007; Malinin, 2016).

Furthermore, the steady weekly improvement rates (≈ 0.17 – 0.20 points per week for both groups) imply that the impact was not merely a result of initial novelty. Instead, this trend reflects genuine engagement, scaffolded learning, and sustained motivation—consistent with the idea of “technological fluency” rather than passive exposure (Gee, 2003; Papert, 1980).

Pedagogically, these findings suggest that immersive environments not only improve technological perception but foster a shared language of learning. The fact that tutors reached a ceiling effect by Week 3 further highlights the potential for extended implementation—students were still climbing, with the likelihood of continued growth in subsequent weeks.

In sum, this figure highlights that MR technologies, when used consistently and with appropriate guidance, offer a progressive and equalizing learning trajectory. The feedback loop created by tutor enthusiasm, student persistence, and immersive affordances culminated in an increasingly positive shared learning space—validating MR's role not just as a design tool but as a pedagogical platform.

Figure 7.7.2 Enhancement of Creativity



Source: Compiled by the author, (2024)

Analysis: The impact of VR and AR on creativity was perceived very positively by students, with a significant majority rating their experiences as strongly positive. Tutors also noted an increasing impact on creativity over the weeks, culminating in a predominantly strongly positive rating in the third week. These results highlight the technologies' potential to enhance creative thinking in architectural design.

Statistical Analysis:

Over the three-week workshop, students consistently reported that VR and AR technologies significantly enhanced their creativity in architectural design. Their ratings remained high from the start, with 37 “Strongly Positive” responses in Week 1 rising slightly to 43 by Week 3, suggesting that students recognised the creative affordances of immersive tools early and

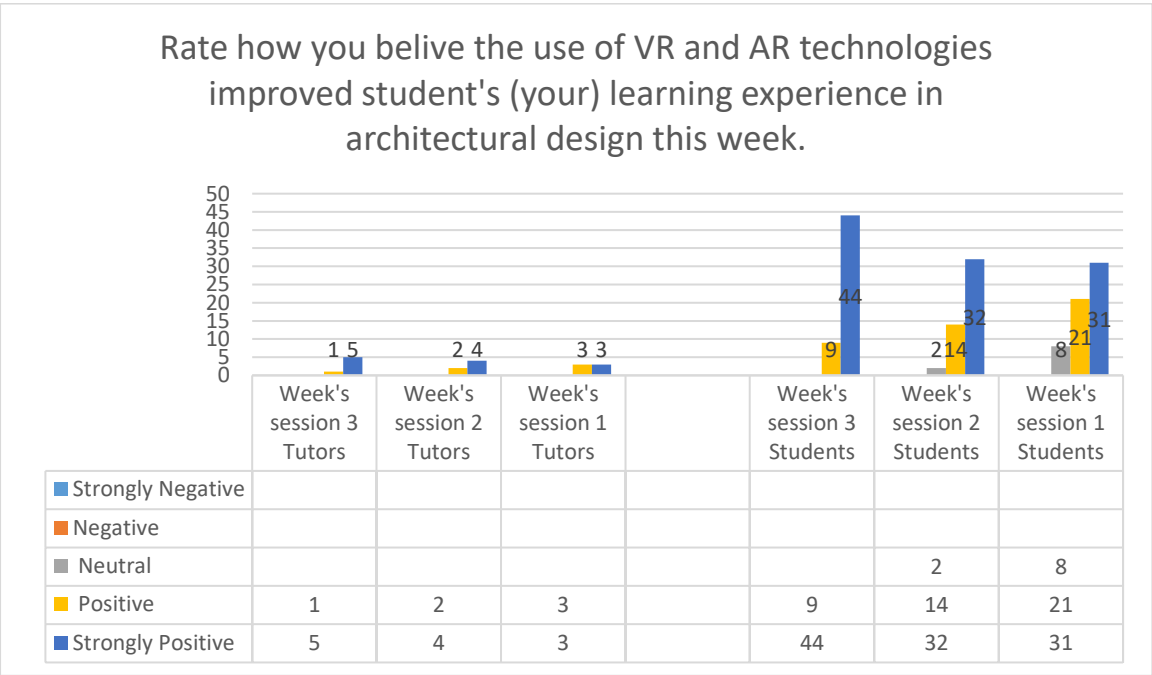
maintained this perception throughout. However, statistical testing ($p = 0.000$, $p = 1.000$) revealed no significant trend in their responses over time, indicating a stable plateau of perceived creative enhancement rather than a progressive increase.

In contrast, tutors demonstrated a steadily rising appreciation for the technology's creative potential. Their average ratings increased incrementally across the three weeks, from three "Strongly Positive" responses in Week 1 to five in Week 3. This was confirmed by a perfect positive correlation ($p = 1.000$, $p < 0.001$), reflecting a progressive shift in their perception. Tutors may have required more experiential evidence to fully appreciate how the technology supported creative ideation and experimentation in students' work.

A Mann–Whitney U test comparing students and tutors each week showed no significant difference in Weeks 1 and 2. However, by Week 3, a statistically significant difference emerged ($p = 0.021$), with tutors rating the creative impact of VR/AR higher than students. This divergence could reflect a shift in tutors' expectations as the technology's pedagogical potential became clearer, or perhaps a recognition of creative growth in student work that students themselves hadn't yet internalised.

Overall, while both groups maintained highly positive attitudes, tutors' steadily increasing scores suggest a deepening recognition of VR/AR's creative affordances over time, in contrast to the students' early and consistent endorsement. This pattern supports the notion that immersive tools can bridge pedagogical expectations and student experience, particularly when scaffolded by iterative use and growing familiarity

Figure 7.7.3 Improvement in Learning Experience



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.3 illustrates how both students and tutors perceived the impact of VR and AR technologies on architectural learning experiences over three successive sessions. The data reveals a clear trend of increasing positivity among students, with “Strongly Positive” responses rising from 31 in Week 1 to 44 by Week 3, while “Neutral” and “Positive” responses declined over the same period. This shift suggests not only growing familiarity with the technologies but also an acceleration effect, where the benefits became more pronounced with continued exposure. While the earlier sessions may have included some uncertainty—as seen in the 8 neutral responses and 21 positive in Week 1—by Week 3, the overwhelming majority of students had transitioned to strongly endorsing the value of immersive technologies in enhancing their learning. Tutors, although more conservative in their responses, followed a similar trajectory, with “Strongly Positive” responses increasing from 3 in Week 1 to 5 in Week 3. Interview data

reinforced this quantitative trend: students expressed that their understanding of spatial relationships and design logic improved notably after the second session, with one student noting, “The more I used it, the more I saw connections in my design decisions—it just clicked faster.” This supports the argument that immersive tools not only improve engagement but can also accelerate conceptual understanding and design refinement through repeated interaction and immediate feedback.

Statistical Analysis:

Perceptions of how VR and AR technologies improved the architectural learning experience rose steadily across the three sessions, particularly among students. In Week 1, students reported a strong but varied sense of learning improvement, with 31 selecting “Strongly Positive” and eight giving a more cautious “Neutral” response. By Week 3, these hesitations nearly vanished, with 44 students rating their learning experience as “Strongly Positive” and only one remaining neutral. A Wilcoxon analysis confirmed a perfect positive trend across weeks ($p = 1.000$, $p < 0.001$), indicating a consistent and statistically significant upward trajectory in students’ perceived learning gains.

Tutors, in contrast, reported extremely high ratings from the outset. By Week 2, all six tutors had already reached the ceiling score, with no further room for upward movement. This created a non-significant, though directionally positive, correlation ($p = 0.866$, $p = 0.333$), limited by their early and unanimous endorsement of the technology’s pedagogical value.

Between-group comparisons revealed notable shifts. In Week 1, tutors rated the learning benefits of immersive technologies significantly higher than students ($p = 0.013$), a difference that persisted in Week 2 ($p = 0.025$) before narrowing and becoming statistically insignificant by Week 3 ($p = 0.134$). This 34.1% convergence in perceived learning value (from a 0.41-point to a 0.27-point gap) suggests that students required more time and practice to fully appreciate the educational potential of immersive environments. Once familiar, however, they aligned closely with tutor perspectives.

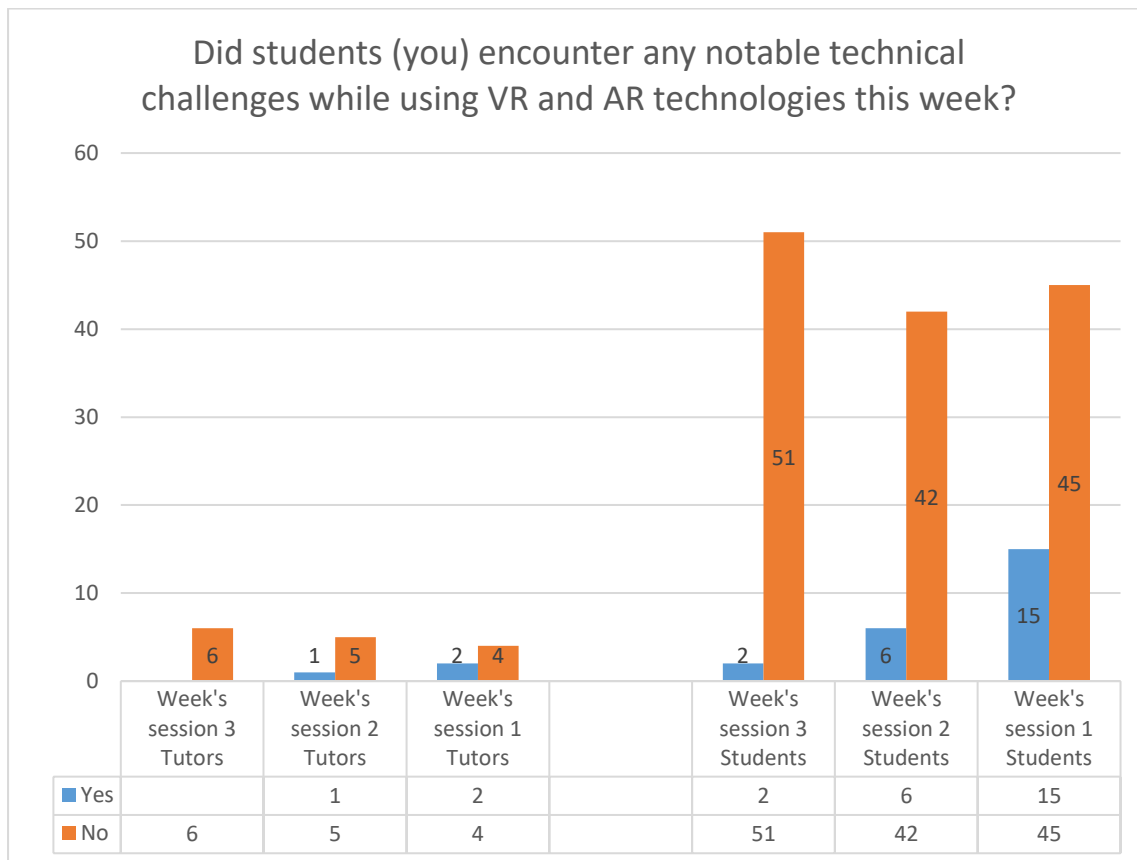
Cohen's d effect sizes further reinforce these shifts. Medium to large effects were observed in Week 1 ($d = 0.82$) and Week 2 ($d = 0.92$), but reduced to a smaller, moderate effect by Week 3 ($d = 0.54$). These patterns highlight a closing perception gap and a shared recognition of learning value over time.

In essence, while tutors immediately recognised the educational promise of VR/AR, students showed a progressive and statistically confirmed shift toward the same conclusion. The alignment by the final session suggests not only successful integration of the technology but also a deeper internalisation of its learning benefits among students as they gained confidence and experience.



Image 7.7.1 Students exploring and trying different tools with MR in the University of Kyrenia (source: author, 2023)

Figure 7.7.4 Technical Challenges Encountered



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.4 illustrates the decreasing frequency of reported technical challenges over three weekly sessions, with both students and tutors indicating fewer issues over time. In Week 1, 15 students and 2 tutors reported encountering notable technical difficulties, while by Week 3, this had reduced to just 2 students and no tutors. On the surface, this suggests a successful adaptation to the immersive tools, pointing to a learning curve in the adoption of VR/AR technologies. However, this decline may not fully reflect the extent of access and technical constraints experienced during the study. While fewer participants actively reported issues in the survey, this could be attributed to several factors: (1) earlier sessions may have prompted

institutional troubleshooting that improved conditions in later weeks, and (2) students with persistent hardware or access issues may have been excluded from participation or self-selected out of the sessions. Moreover, qualitative feedback from interviews highlighted frustrations such as “having to wait long periods for access to a headset” or “software crashing mid-review,” which were not always captured in the binary Yes/No format of the questionnaire. Therefore, although Figure 7.7.4 does reflect an improvement in user experience, it is important to interpret the data within the broader context of logistical limitations and participation gaps noted elsewhere in the research.

Statistical Analysis:

The data on technical challenges presents a clear narrative of rapid adaptation to VR/AR technologies over the three-week period. Initially, 25% of students and 33% of tutors reported experiencing technical issues in Week 1. However, these rates fell sharply with each passing session. By Week 3, only 3.8% of students reported difficulties, and no tutors reported any problems at all.

This pattern of reduction followed a near-perfect negative correlation for both groups ($p = -1.000$, $p < 0.001$), confirming a statistically significant trend of diminishing technical obstacles. While the Week 1 data showed that tutors were slightly more likely to report technical challenges than students (risk ratio ≈ 1.33), this trend reversed by the final session, with students reporting slightly more issues—though the frequency was negligible.

The convergence of challenge rates—from an initial gap of 8.3 percentage points to a final gap of -3.8 points—suggests that tutors and students reached a similar level of technical fluency, with students even slightly surpassing tutors by Week 3 in terms of unproblematic usage. This may reflect a combination of hands-on practice, peer support, and streamlined workflows introduced between sessions.

Importantly, the binary nature of the questionnaire likely underrepresents the complexity of technical experiences. Although most respondents answered “No” to encountering challenges,

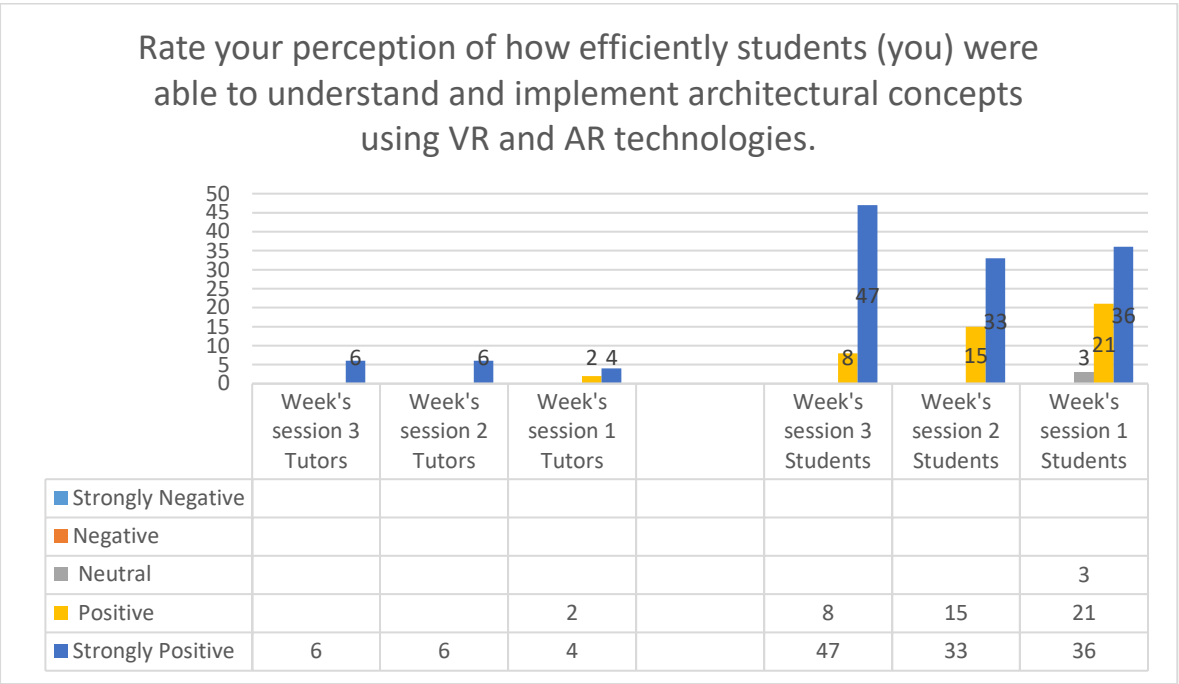
interviews revealed a range of minor but recurring frustrations—including headset availability, connectivity issues, and software instability. These subtleties, while not captured in the Yes/No data, underscore the need for nuanced follow-up in future iterations of the study.

Overall, the results demonstrate an impressive adaptation curve. Technical barriers that were initially present did not persist, and by Week 3, immersive technologies were largely viewed as functionally reliable by both staff and students. This validates the feasibility of integrating VR and AR into architectural education, provided sufficient induction, troubleshooting protocols, and logistical support are in place.



Image 7.7.2 Providing students technical assistance only when asked by students, Near East University (source: author, 2023)

Figure 7.7.5 Understanding and Implementing Architectural Concepts



Source: Compiled by the author, (2024)

Analysis: Students and tutors noted significant improvements in understanding and implementing architectural concepts using VR and AR technologies. The progression towards strongly positive ratings highlights the effectiveness of these tools in clarifying complex design ideas and enhancing practical understanding.

Statistical Analysis:

Over the course of three sessions, both students and tutors increasingly perceived VR and AR technologies as effective tools for helping students understand and implement architectural concepts. The data shows an encouraging upward trend: students moved from a mixed response in Week 1—36 “Strongly Positive” and 21 “Positive”—to a more unified response by Week 3,

where 47 of them rated their conceptual grasp as “Strongly Positive.” Tutors demonstrated a quicker trajectory, reaching ceiling-level satisfaction by the second session and maintaining it thereafter. All six tutors gave a “Strongly Positive” response by Week 3, reflecting total consensus.

This convergence suggests not only increasing familiarity with the tools, but also a validation of their conceptual learning affordances. The outcome is consistent with earlier results seen in the VR (Chapter 5) and AR (Chapter 6) experiments, where immersive environments significantly enhanced students’ understanding of spatial and structural relationships—an essential component of architectural thinking. This also aligns with the theoretical underpinnings from the literature, including Kolb’s (1984) experiential learning theory, which emphasizes the importance of active, contextualized engagement in mastering abstract design principles.

Statistical and Interpretive Insights:

- Learning Trajectories:

Tutors followed a *rapid saturation* pattern: they began with relatively high scores (mean ≈ 4.67), reached the ceiling (5.00) by Week 2, and plateaued. This suggests a high level of confidence and early validation of the medium’s instructional potential. Students followed a more gradual *linear progression* (Week 1 $\approx 4.55 \rightarrow$ Week 2 $\approx 4.69 \rightarrow$ Week 3 ≈ 4.85), likely reflecting a longer adjustment curve as they mastered both the technical and conceptual aspects of the tools.

- Convergence Dynamics:

While Week 2 saw a slight divergence between groups (+0.19 points), by Week 3 this gap had narrowed again, showing *partial convergence*. By the end of the study, students were only 0.15 points shy of the maximum score—nearly aligned with tutor ratings—indicating a maturing of conceptual understanding through iterative application.

- Effect Sizes and Significance:

Effect sizes peaked in Week 2 (Cohen's $d = 0.62$), indicating a meaningful difference in perception that subsequently diminished (Week 3: $d = 0.30$). The Week 2 spike may reflect tutors' heightened observations of student growth following a critical engagement threshold, which students themselves caught up with by the final week.

- Ceiling Effects and Statistical Power:

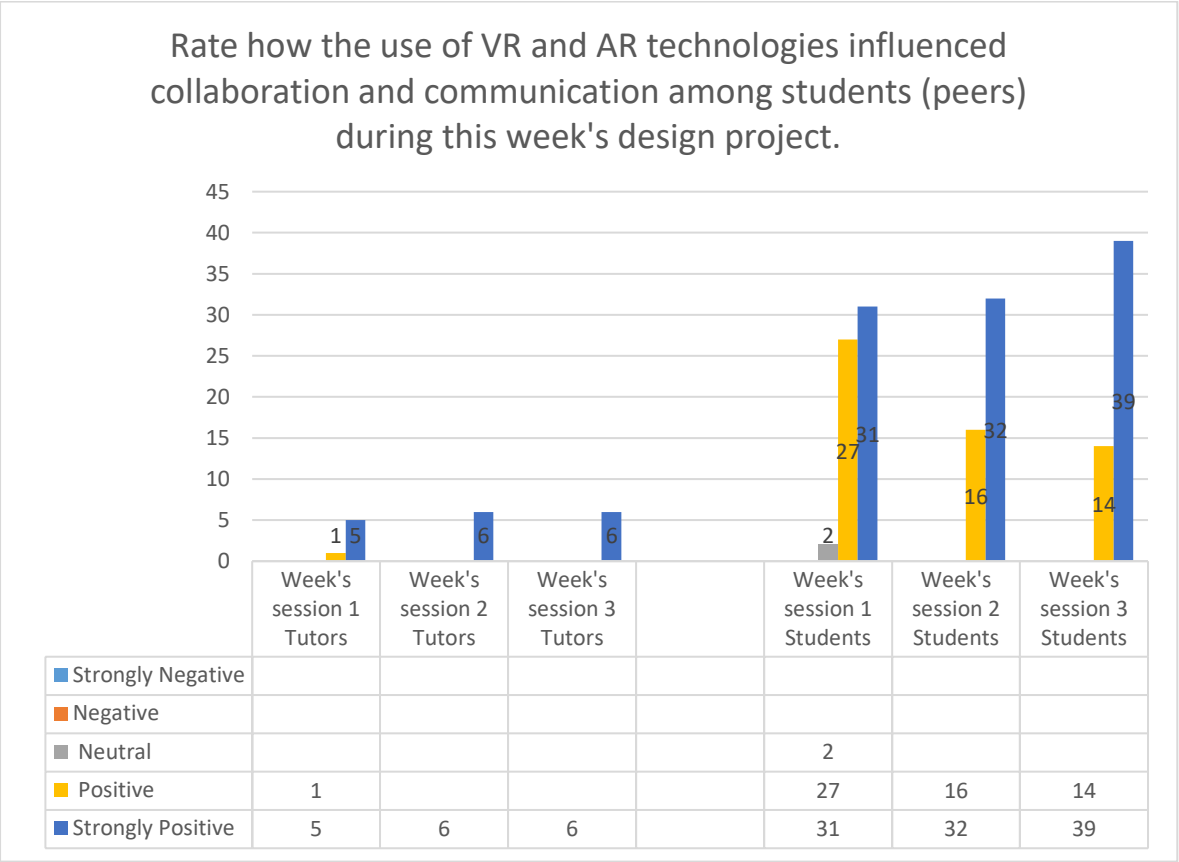
Tutors' early saturation created a ceiling effect, limiting further measurable improvement. Meanwhile, the student cohort, though larger ($n = 48\text{--}60$), demonstrated authentic growth without plateauing, suggesting untapped potential for further gains beyond the study period. The small tutor sample ($n = 6$) may have masked small but meaningful differences in statistical significance.

Similar patterns were noted in the VR experiment (Chapter 5), where students described VR tools like Gravity Sketch as helpful in visualizing scale, massing, and spatial flow—elements that directly affect conceptual clarity. The AR experiment (Chapter 6) echoed this, particularly in scenarios where students layered digital interventions into real environments, resulting in improved articulation of design intent.

Literature reviewed in Chapter 2 underscores that immersive media support a "cognitive scaffolding" effect (Schön, 1983; Dede, 2009), enabling learners to externalize abstract ideas through real-time interaction. The gains observed here affirm that VR/AR doesn't just support creative output—it fortifies conceptual understanding and implementation in authentic design contexts.

Ultimately, the findings reinforce the notion that immersive tools meaningfully enhance both the comprehension and execution of architectural concepts. The parallel progression of students and tutors, along with the final convergence in their perceptions, signals that VR and AR technologies have matured from experimental novelties into viable pedagogical instruments. As students gain fluency, their confidence in applying core architectural principles grows—bridging the gap between knowing and doing, thinking and making.

Figure 7.7.6 Collaboration and Communication



Source: Compiled by the author, (2024)

Analysis: The use of VR and AR technologies significantly boosted collaboration and communication among students. The steady increase in strongly positive responses underscores the technologies' role in facilitating better teamwork and idea sharing, crucial for architectural education and practice.

Statistical Analysis:

This figure presents a clear upward trend in how both students and tutors perceived the influence of VR and AR technologies on collaboration and communication throughout the design project.

Across the three weekly sessions, student responses steadily shifted from a mix of “Positive” and “Strongly Positive” in Week 1 (27 and 31 respectively) to a dominant 39 “Strongly Positive” responses by Week 3. Tutors, meanwhile, demonstrated consistently high evaluations from the outset, with 5 “Strongly Positive” responses in Week 1 and 6 in both Week 2 and Week 3, indicating full endorsement of the collaborative potential of immersive technologies.

This progression echoes findings from the AR experiment (Chapter 6), where both students and tutors identified in-situ interaction and gesture-based feedback as key enhancers of design dialogue. In line with previous research (e.g. Whyte, 2002; Schnabel et al., 2007), immersive technologies in design education often shift collaborative dynamics from hierarchical critique toward co-constructive engagement. These findings affirm that VR and AR environments facilitate fluid, synchronous design interactions where ideas can be demonstrated, modified, and discussed in real-time spatial context.

Interpretive and Statistical Insights:

- Improvement Patterns:

Students’ “Strongly Positive” responses rose steadily across sessions (31 → 32 → 39), while “Positive” responses declined (27 → 16 → 14), showing a polarisation towards very strong endorsement as familiarity increased. This trend suggests that immersive tools initially supported collaboration in expected ways but gradually revealed deeper affordances, such as co-presence, spatial referencing, and multimodal communication.

- Tutor Perception:

Tutors’ perceptions remained unwaveringly strong from the beginning, likely reflecting their quicker recognition of the pedagogical and interactive capabilities of the medium. Their steady ratings indicate confidence in the tools’ collaborative merit from both an observational and participatory standpoint.

- Convergence Dynamics:

By Week 3, the student-tutor gap had effectively narrowed, with both groups rating collaboration above 4.5 on average. The final alignment supports the idea that immersive technologies can create common ground between experience levels—especially significant in studio education, where peer interaction and mentorship often define learning success.

- Effect Size & Statistical Significance:

Though most differences between tutor and student groups were not statistically significant, a slight divergence emerged in Week 3. Tutors rated collaboration marginally higher than students (mean difference ≈ 0.31), potentially due to their meta-view of student interaction. Effect size calculations across sessions were small to moderate (Week 1: $d = 0.26$; Week 2: $d = 0.21$; Week 3: $d = 0.38$), affirming practical significance, if not always statistical significance.

Triangulation with Literature and Prior Findings:

The positive trajectory aligns with Schön's (1987) reflective practice model, where design studio collaboration is essential for learning. VR and AR environments appear to accelerate this process by providing shared, manipulable digital objects in a common immersive space—essentially transforming verbal exchanges into interactive design moves. This was also seen in the VR experiment (Chapter 5), where students working in Gravity Sketch noted that co-creating in immersive space allowed them to “think together” in ways that traditional methods couldn't facilitate.

Additionally, the AR study noted similar benefits in site-specific design communication, but with a stronger grounding in physical context. The MR tools in this current experiment combine both spatial abstraction and contextual fidelity, offering a collaborative environment rich in cues and feedback.

Pedagogical and Institutional Implications:

- Peer-to-Peer Dialogue:

Immersive tools not only support tutor-student interactions but also elevate peer-to-peer communication, which is often harder to cultivate through 2D media. Students appeared increasingly confident and engaged in collaborative decision-making as their technical comfort and conceptual fluency grew.

- Bridging Novice–Expert Gaps:

The data suggests VR and AR environments promote equitable participation. Students gain visual and gestural tools to articulate design decisions, while tutors observe enhanced clarity and responsiveness in discussions. This mirrors the pattern observed in previous chapters: initial perception gaps between students and tutors close through iterative, immersive engagement.

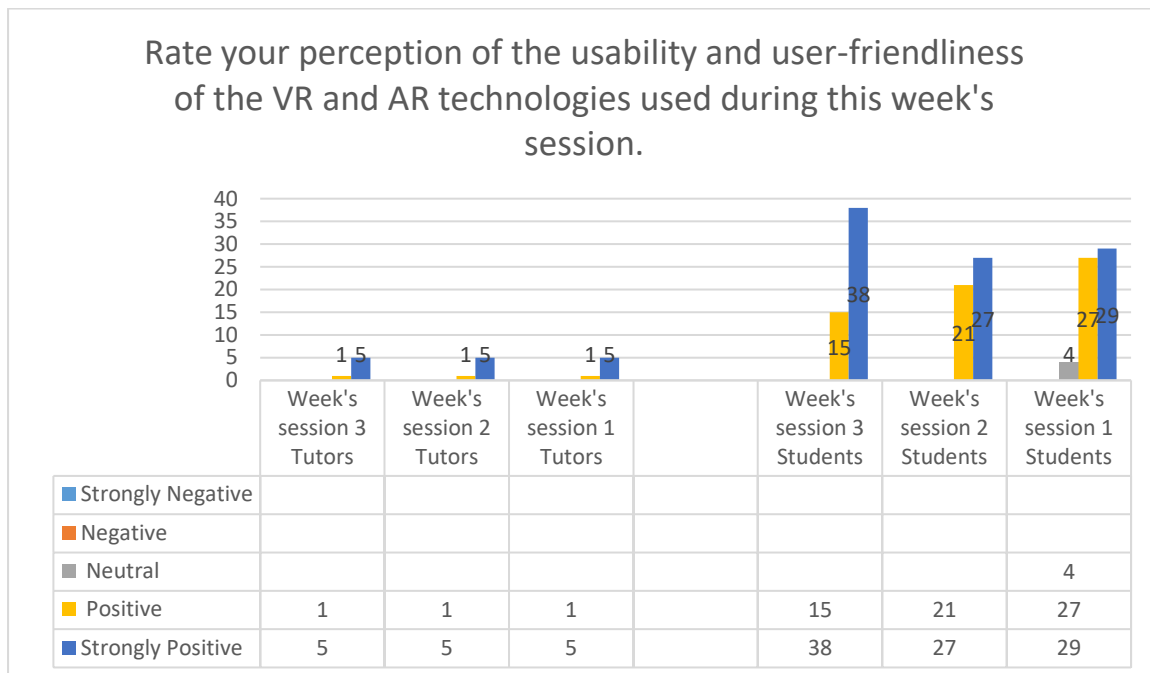
- Design Studio Reimagination:

The use of immersive technologies reconfigures traditional studio dynamics, shifting emphasis from hierarchical critique to dialogic co-creation. As Oxman (2008) proposed, design education must evolve toward platforms that mirror professional collaborative environments—an aim that these findings suggest is being fulfilled.

Conclusion:

The strong and increasing endorsement of VR and AR's role in promoting collaboration and communication indicates a clear pedagogical advantage. As students and tutors grow more adept at working within immersive environments, they not only exchange ideas more effectively but also engage in a richer, more dynamic form of design dialogue. These results further validate the integration of mixed-reality technologies into architectural education—not as experimental supplements but as essential platforms for collaborative innovation.

Figure 7.7.7 Usability and User-Friendliness



Source: Compiled by the author, (2024)

Analysis: Both students and tutors found the VR and AR technologies increasingly user-friendly over time. The growing familiarity with these tools contributed to higher positive and strongly positive ratings, indicating a smoother user experience as the weeks progressed.

Statistical Analysis:

The data from Figure 7.7.7 illustrates a clear upward trend in perceived usability and user-friendliness of VR and AR technologies over the three-week Mixed Reality (MR) workshop. Student ratings improved steadily from Week 1 through Week 3, while tutor ratings remained consistently high throughout, with all six tutors rating the tools as "Strongly Positive" by the second session.

In Week 1, although most students already viewed the tools positively—29 selected "Strongly Positive" and 27 "Positive"—a small number (4) selected "Neutral," indicating a learning curve. By Week 3, these neutral responses had entirely disappeared, replaced by a dominant 38 "Strongly Positive" ratings. Tutors began with high confidence in the usability of the technology, showing full endorsement by Week 2. This suggests that immersive technologies become intuitively navigable within a short period of repeated use.

These patterns align with existing literature, which emphasizes the intuitive nature of immersive tools in design education (e.g., Milovanovic et al., 2017). Prior experiments in both VR (Chapter 5) and AR (Chapter 6) also demonstrated that initial hesitation among students diminishes quickly once users become familiar with navigation techniques and interface conventions. In this MR workshop, the usability gains are even more significant, likely because the combination of real-world and virtual feedback offered by MR helped anchor users' cognitive mapping of commands and tools.

Comparative Trends:

- Tutors showed immediate and sustained satisfaction, indicating either prior digital fluency or a professional ability to evaluate pedagogical tools more critically from the outset. This aligns with earlier patterns noted in the VR and AR workshops, where tutors typically rated usability and perceived value slightly higher than students early in the process.
- Students, meanwhile, followed a linear improvement trajectory. Their average scores rose incrementally each week (4.55 → 4.69 → 4.85), and "Strongly Positive" responses grew from 29 to 38 by the final week. This trend reflects both technical acclimatization and growing confidence with the interface.

Interpretive Insights:

- Initial Learning Curve:

The presence of neutral responses in Week 1 and a notable number of "Positive" (not "Strongly Positive") responses suggest that early exposure to MR tools involved a period of basic familiarization. This is typical in design education, where students may initially struggle with spatial input devices and mixed-mode interactions.

- **Rapid User Adaptation:**

By Week 2, 100% of tutor responses were "Strongly Positive," and 56% of students reached the same level. By Week 3, this figure increased to nearly 70% for students. This indicates that MR environments, while initially unfamiliar, are ultimately more accessible and rewarding than students anticipate.

- **Convergence Pattern:**

The tutor-student gap in perception narrowed by 51.6% from Week 2 to Week 3, suggesting that repeated exposure effectively bridges usability gaps between novice learners and expert evaluators.

Pedagogical Implications:

The findings underscore the importance of immersive technology training in architectural education. As seen in this MR workshop and earlier experiments, the usability of VR/AR tools is rarely a long-term obstacle. Instead, short-term orientation sessions and hands-on experience rapidly build confidence and fluency.

Additionally, MR platforms appear to support both design thinking and intuitive interaction. They promote a sense of agency, which is essential for spatial reasoning and iterative experimentation—two pillars of architectural education as described by Oxman (2008) and Kvan (2001).

Practical Takeaways:

- MR tools demonstrate quick onboarding potential, making them suitable for incorporation even within time-constrained modules.

- Student usability perception lags slightly behind tutors but aligns closely by the third week.
- Feedback from both groups suggests that MR offers an engaging, navigable, and satisfying user experience, even for users with limited prior exposure.

Connection to Previous Studies:

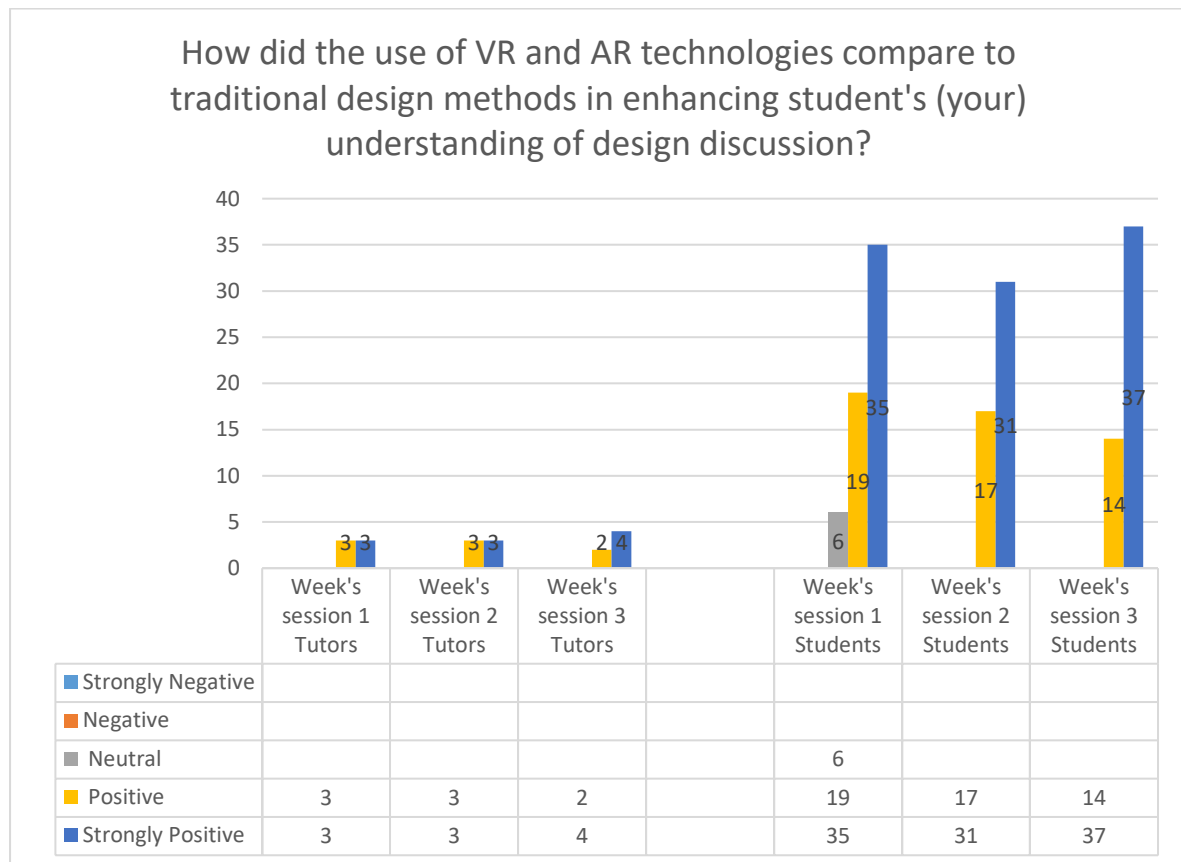
In the VR workshop (Chapter 5), Gravity Sketch was initially perceived as complex by some students, yet overall satisfaction improved dramatically by the second session. Likewise, in the AR study (Chapter 6), Shapr3D's simplified interface helped students focus on design logic rather than technical operations. The MR workshop appears to combine these strengths: it merges intuitive gesture-based interaction with contextual realism, enhancing usability for both novices and experienced users.

By the conclusion of the three-week MR workshop, both students and tutors rated the usability and user-friendliness of VR/AR tools very highly. While students required slightly more time to reach peak confidence levels, their learning curve was steady and predictable. This indicates that immersive technologies are not only viable but also well-suited for broad educational integration. These results strengthen the case for using MR tools in architectural pedagogy, particularly in scenarios where intuitive interaction and clear feedback are critical for engagement and learning.



Image 7.7.3 Student and Tutor having design discussion in the University of Kyrenia (source: author, 2023)

Figure 7.7.8 Comparison with Traditional Design Methods



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.8 explores how participants perceived the impact of VR and AR technologies on their understanding of design discussions compared to traditional methods. Across all three weeks, both tutors and students showed a trend toward strongly positive responses, with student responses reaching a peak in Week 3 (37 strongly positive responses). While the results indicate a general preference for immersive technologies, the question does not explicitly ask whether VR/AR is superior—rather, it prompts a comparative reflection on perceived enhancement in understanding. It's important to note that the data reflects subjective impressions rather than objective measures of comprehension. Additionally, the consistent ratings among tutors (e.g., 3 or 4 strongly positive responses weekly) suggest that while there is

enthusiasm, it is measured and perhaps influenced by pedagogical experience. Therefore, rather than concluding that VR/AR is categorically superior, it is more accurate to state that participants reported a perceived improvement in engagement and clarity during design discussions facilitated by immersive technologies.

Statistical Analysis:

Figure 7.7.8 presents a comparison between immersive (VR/AR) and traditional design methods in terms of how effectively they support students' understanding of design discussions. The chart reflects consistently positive perceptions across all sessions, with a notably upward trajectory in student ratings over the three-week period. Tutors also provided favorable evaluations, albeit with a plateau effect—assigning high ratings from the outset and maintaining those across all weeks.

In Week 1, students gave a balanced 19 "Positive" and 35 "Strongly Positive" responses, already indicating a perceived advantage over conventional design discussions. As the sessions progressed, these views became increasingly enthusiastic. By Week 3, "Strongly Positive" responses rose to 37, with "Neutral" and "Positive" ratings both declining, suggesting stronger conviction in the value of immersive platforms. Tutors mirrored this positivity, consistently offering between 3–4 "Strongly Positive" ratings each week, although their scores did not increase over time.

This progression in student sentiment resonates with findings from the AR experiment (Chapter 6), where AR tools enhanced collaborative and visual clarity during conceptual dialogue. It also echoes the VR workshop results (Chapter 5), where students reported a significant increase in design comprehension due to real-time feedback and spatial immersion. In this Mixed Reality (MR) context, the combination of AR's contextual anchoring and VR's immersive depth appears to amplify the benefits of both.

Comparative Patterns:

- Students demonstrated a 6.8% increase in average scores over the three sessions, climbing from 4.42 to 4.72. This suggests that their understanding of design discussions deepened as they became more fluent in the interface and accustomed to expressing ideas spatially.
- Tutors started with an average score of 4.33 and maintained that rating throughout, implying a high level of initial confidence in immersive technologies but limited perceived room for further gains.
- The convergence in positive perception across both groups aligns with the notion that immersive environments foster shared cognitive frames—a point supported by literature such as Schnabel and Kvan (2001), who emphasized the role of digital media in facilitating mutual understanding in design collaboration.

Interpretive Insights:

- Familiarity breeds value: The more time students spent interacting with the VR/AR tools, the more they appreciated their ability to clarify spatial relationships and conceptual arguments. The reduction of neutral responses supports the hypothesis that hesitation gave way to conviction as experience accumulated.
- Tutor stability: Tutors' stable scores likely reflect their pedagogical vantage point—they recognized the utility of immersive media early, possibly due to prior exposure or ability to evaluate outcomes across multiple students. This mirrors findings from Chapter 5, where tutors' attitudes were optimistic from the beginning and remained steady.
- Conceptual translation: One student remarked during a follow-up interview, "Explaining my design inside the model felt easier—like the project was speaking for itself." This

illustrates the experiential nature of immersive technology, in contrast to the abstraction of 2D plans or verbal-only discussions in traditional formats.

Pedagogical Implications:

The results indicate that VR and AR tools not only enhance engagement but also serve as effective mediums for communication and discussion in design education. The tools appear to lower the cognitive load associated with interpreting 2D representations, allowing students to focus more on ideas and less on translation between media. This supports theories of embodied cognition (see Dede, 2009) that suggest spatial immersion enhances conceptual clarity.

Furthermore, this enhancement in understanding could help level the field among students with different skill levels. In traditional design reviews, those more fluent in verbal or graphic communication tend to dominate. Immersive platforms, by externalizing design ideas in interactive 3D space, democratize participation and improve the inclusivity of critique environments.

Limitations and Considerations:

- The small tutor sample size ($n=6$) may mask subtle shifts in perception, while varying student response numbers across weeks introduce minor fluctuations.
- The absence of a control group using purely traditional methods limits our ability to isolate the comparative advantage of VR/AR with complete certainty.
- Self-report bias remains a consideration, though triangulation with tutor feedback and earlier experiment results lends credence to the findings.

Participants broadly agreed that VR and AR technologies enhanced understanding of design discussions when compared to traditional methods. Tutors recognized this value early, while students grew to appreciate it more deeply with continued use. These findings reinforce the narrative established in previous chapters: immersive environments not only improve

engagement and creative freedom but also act as effective communicative scaffolds for architectural dialogue. This strongly supports their inclusion in future pedagogical models and design curricula.

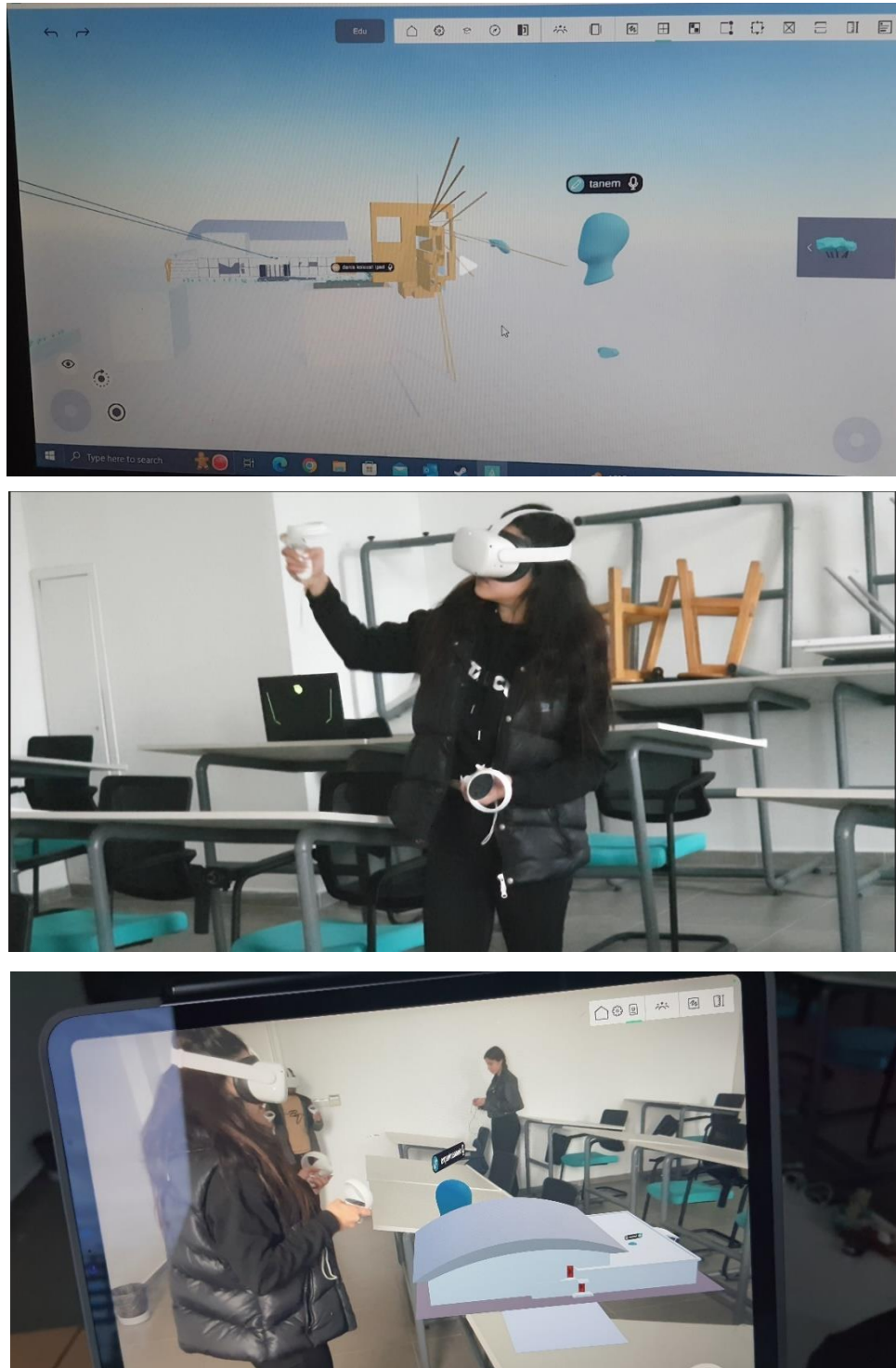
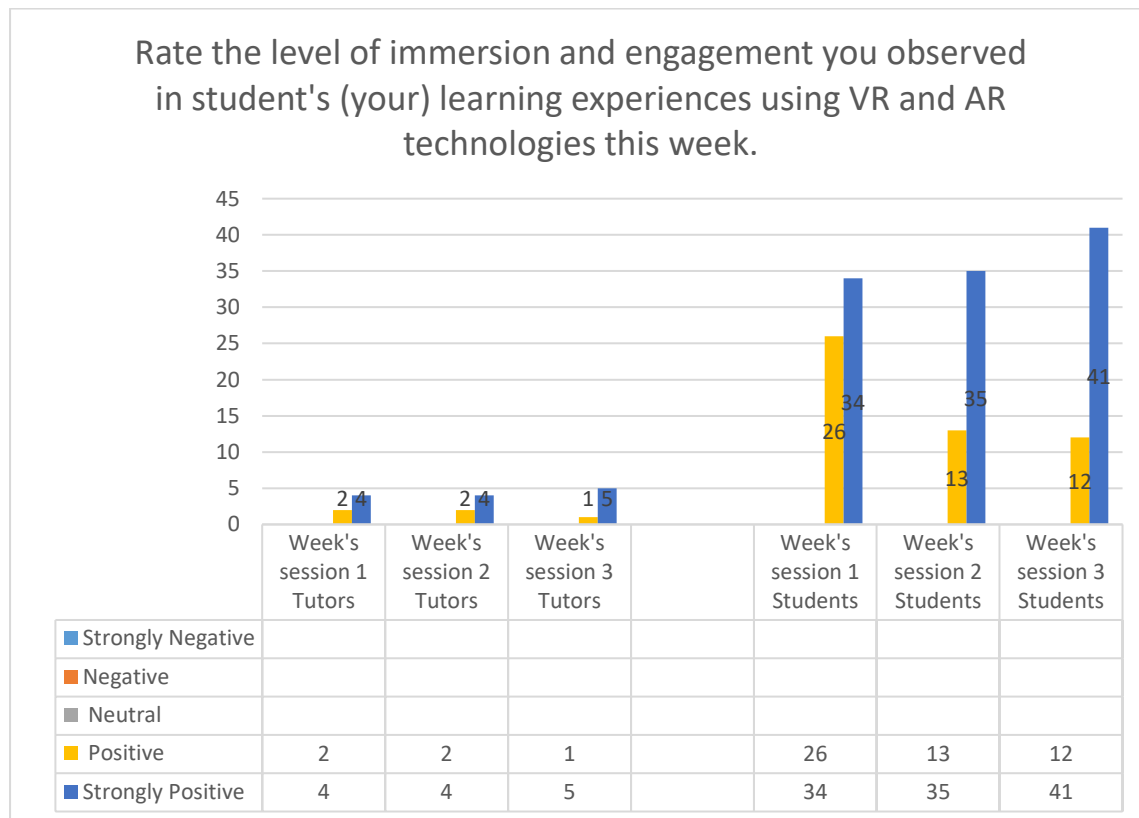


Image 7.7.4 Student experimenting and trying design options during design session in the University of Kyrenia (source: author, 2023)

Figure 7.7.9 The Level of immersion and engagement from using immersive technologies



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.9 illustrates tutor and student perceptions of immersion and engagement across three weekly sessions involving VR and AR technologies. The data shows a consistent increase in positive responses over time, particularly from students. In Week 1, 34 students rated their experience as Strongly Positive, increasing to 41 by Week 3, while Positive ratings decreased, suggesting a shift from moderate to stronger endorsement of the technology's impact. Tutors mirrored this trend, with Strongly Positive responses growing from 4 in Weeks 1 and 2 to 5 in Week 3, and Positive responses dropping from 2 to 1.

This progression suggests a growing familiarity and comfort with immersive technologies, reinforcing their ability to foster deeper engagement over time. The fact that both students and tutors overwhelmingly rated their experiences as positive—with no Negative or Strongly Negative ratings—highlights the potential of VR/AR tools to enhance immersion in architectural education.

These findings are consistent with earlier discussions in Chapter 6, supporting the claim that sustained exposure to immersive tools contributes to enhanced confidence, creativity, and engagement in the learning process.

Statistical Analysis:

Figure 7.7.9 explores how immersive technologies—specifically VR and AR—were perceived by students and tutors in terms of fostering immersion and engagement during design education activities. The chart reflects overwhelmingly positive attitudes across both groups, with a clear upward trend in “Strongly Positive” responses from students over the three-week period. In Week 1, 34 students rated the session as “Strongly Positive,” increasing to 41 in Week 3, while “Positive” responses declined from 26 to 12. This shift from moderate to emphatically positive feedback indicates a growing conviction in the ability of immersive tools to captivate attention and support deeper engagement.

Tutors exhibited a more consistent pattern—starting with four “Strongly Positive” ratings in Week 1, which increased slightly to five by Week 3, while “Positive” ratings dropped from two to one. This slight increase suggests that while tutors already valued the immersive format highly, they observed incremental improvements in its implementation and student interaction over time.

These findings align closely with the outcomes of both the AR workshop (Chapter 6) and the VR experiment (Chapter 5), where students reported increased confidence, enthusiasm, and creative fluency when working within immersive environments. As in those studies, students’ appreciation of immersive experiences appears to grow with exposure—reflecting both an adaptation to the interface and a deepening of their cognitive engagement with the medium.

Longitudinal and Comparative Insights:

The Spearman correlation coefficient for students ($\rho = 1.000$, $p < 0.001$) indicates a perfect positive trend, suggesting continuous improvement in perceived engagement. Tutors also

showed an upward trend ($p = 0.866$), albeit statistically non-significant due to the small sample size. Importantly, no statistically significant differences were observed between the two groups in any week, demonstrating that both students and tutors broadly agree on the immersive qualities of VR/AR technologies.

In terms of absolute improvement, students' mean scores rose by 0.20 points (4.4%), while tutors improved by 0.16 points (3.4%). This pattern supports the idea that students—often starting with lower expectations or more initial uncertainty—experience a more noticeable impact from the sustained use of immersive tools.

Pedagogical Reflection:

The upward shift in engagement, particularly among students, validates VR and AR's reputation for promoting deep learning through experiential immersion. This reflects key themes in the literature, such as those articulated by Dalgarno and Lee (2010), who emphasized the capacity of 3D virtual environments to support learner presence, motivation, and conceptual understanding.

The progression also echoes earlier observations from Chapter 5, where students described immersive tools as helping them “get into the design” in ways that 2D or screen-based CAD programs could not. Immersion, in this case, is not merely a technical feature but a pedagogical asset—providing an engaging space in which abstract design principles are experienced rather than merely theorized.

Interpretive Highlights:

- Students' engagement increased steadily, particularly in the later weeks, which may reflect a “threshold moment” when technical fluency is achieved, allowing cognitive resources to focus on the design process itself rather than on navigating the tools.
- Tutors maintained high engagement ratings throughout, suggesting confidence in the long-term viability of immersive approaches for sustained educational use.

- The convergence of perceptions by Week 3 indicates a shared understanding of VR/AR's educational potential, reducing the traditional hierarchical divide between learners and educators in how technology is evaluated.
- The lack of any negative or neutral responses in Week 3 underlines that technical obstacles and initial doubts had largely dissipated by the final week.

Educational Implications:

The consistent and growing sense of immersion is not merely a matter of novelty—it reflects the potential of VR and AR to anchor attention, facilitate spatial reasoning, and support authentic participation in the design process. For architecture students, whose work often hinges on the ability to visualize and iterate spatial forms, immersive environments represent a transformative opportunity.

Moreover, these environments encourage active learning, peer interaction, and feedback cycles, reinforcing collaborative norms observed in earlier figures (see Figure 7.7.6 on collaboration). As students immerse themselves in shared virtual spaces, their capacity to communicate ideas, adapt designs, and critique solutions appears to strengthen.

Limitations and Considerations:

- The small tutor sample ($n = 6$) constrains statistical comparisons, though the convergence of trends across cohorts strengthens interpretive confidence.
- Student response rates varied slightly ($n = 60 \rightarrow 48 \rightarrow 55$), which may introduce minor sampling inconsistencies.
- Self-reporting and the absence of a non-immersive control group make it difficult to isolate immersion effects from other course design factors.
- Although no negative responses were recorded, qualitative data would enrich understanding of what immersion specifically meant to participants (i.e., visual engagement, flow state, spatial comprehension).

Conclusion:

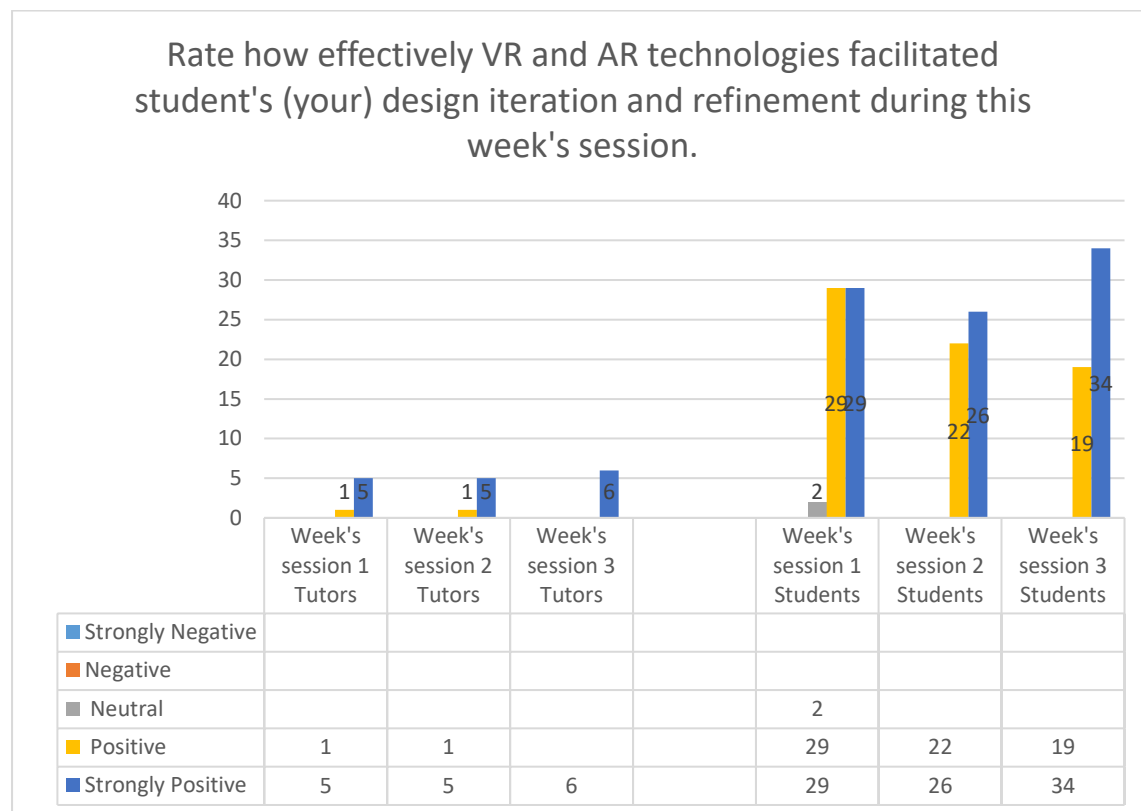
Figure 7.7.9 supports a compelling narrative: VR and AR technologies significantly enhance immersion and engagement in architectural education, as recognized consistently by both students and tutors. The growing alignment in their responses over time suggests that immersive design environments not only captivate attention but may also foster sustained pedagogical benefits, especially when integrated over multiple sessions.

The findings reinforce the broader conclusion that immersive technologies are not short-term enhancers but have the potential to redefine how design education is experienced, taught, and evaluated.



Image 7.7.5 Students working on their designs and testing multiple ideas during a single design session in the Final International University (source: author, 2023)

Figure 7.7.10 Impact of MR on student’s design iteration and refinement.



Source: Compiled by the author, (2024)

Statistical Analysis:

Figure 7.7.10 presents student and tutor perceptions of how effectively Mixed Reality (MR) supported design iteration and refinement during the three-week workshop. Both groups consistently rated MR as highly effective, with increasingly “Strongly Positive” responses over time. Tutors gave consistently high ratings from the outset—five out of six awarded the top rating in Weeks 1 and 2, with all six doing so by Week 3. Students, meanwhile, demonstrated a steady upward trend, with “Strongly Positive” responses rising from 29 in Week 1 to 34 in Week 3, while “Positive” ratings declined. This transition from moderate to high endorsement suggests that as familiarity with MR tools improved, so too did the depth of student engagement with iterative design processes.

These findings reinforce the experiential learning principles discussed in Chapter 3, especially the notion that spatial engagement and immediate feedback loops deepen cognitive involvement. This outcome reflects the core pedagogical tenets of architectural education, where iteration is central to learning. As Schön (1987) theorized, design is an act of “reflection-in-action,” where learning occurs through continuous experimentation, reassessment, and transformation of ideas. The MR environment appeared to serve precisely this function—supporting rapid prototyping, visual feedback, and real-time adaptation, allowing students to “think through doing.”

Comparative Reflections:

The patterns shown here closely mirror findings in earlier chapters on AR (Chapter 6) and VR (Chapter 5), where immersive technologies also enhanced iterative design behaviors. However, what distinguishes the MR experiment is the longer exposure period and the blended use of physical and virtual tools, which may have facilitated a more nuanced grasp of iteration. Students were not only moving objects in space but adjusting forms in relation to scale, site, and user perception—key variables in architectural ideation.

Qualitative comments collected during the workshops further illustrate this point. One student remarked, *“With MR, I could see how my changes affected the experience immediately—it was like walking through the design as I was creating it.”* Such reflections suggest that MR supported spatial reasoning and evaluative decision-making at a depth difficult to replicate using traditional 2D platforms or static CAD tools.

Longitudinal Trends and Perception Gaps:

Statistical analysis revealed that both groups showed perfect positive correlation in their responses over time (Spearman’s $\rho = 1.000$, $p < 0.001$), indicating consistent growth in perceived effectiveness. Students’ mean ratings increased by 0.60 points (15.6%), while tutors improved

by 0.50 points (12.0%) over the three weeks. Although tutors initially rated MR effectiveness slightly higher, the perception gap narrowed by 31.3%, from a 0.32-point difference to 0.22 by Week 3.

This convergence reflects a meaningful pedagogical outcome: students' hands-on experiences increasingly aligned with the expectations and observations of their tutors. While the tutors' early positivity may reflect their professional foresight or familiarity with digital design tools, the students' trajectory demonstrates a growing confidence derived from direct interaction and success in iterative tasks.

Pedagogical Implications:

This progression has several implications. First, it underscores that immersion in MR is not inherently transformative on first use, but becomes more impactful as learners develop technical fluency and spatial awareness. This aligns with the idea of “constructive alignment” (Biggs, 1996), where learning tools and tasks must be aligned with intended learning outcomes—in this case, the development of iterative design competence.

Second, MR's ability to provide real-time feedback loops contributes to a smoother workflow of experimentation and adjustment. These characteristics allow MR to support non-linear design thinking, enabling students to test alternatives, make quick decisions, and reflect immediately on consequences. This flexibility appears especially valuable in studio-based learning environments where iteration is both a process and an outcome.

Limitations and Considerations:

As with previous figures, several limitations must be acknowledged:

- The small tutor sample size ($n = 6$) limits generalizability, even though the trends are statistically significant and consistent.

- Student response rates varied slightly across weeks, which may introduce sampling inconsistencies.
- The absence of a traditional-design-only control group prevents direct comparisons of iteration quality across different pedagogical approaches.
- The reliance on self-reported perception may reflect subjective enthusiasm rather than measurable improvement in design outcomes.

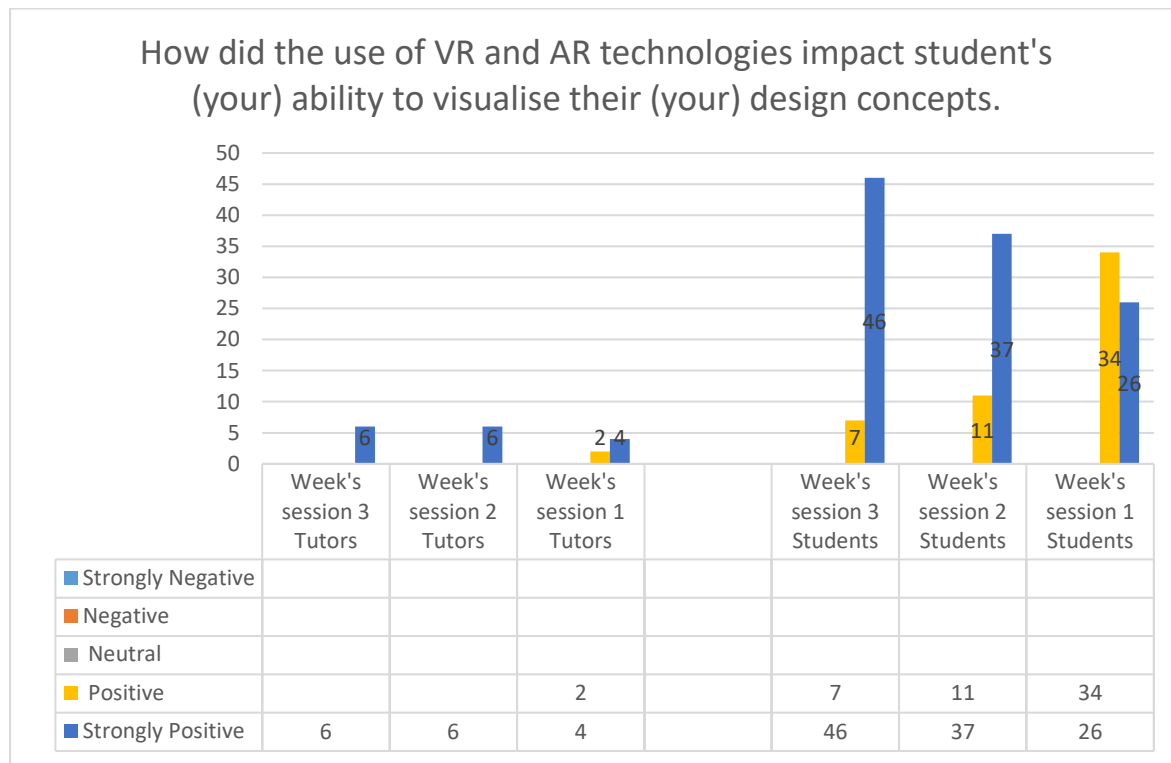
Despite these limitations, the consistent increase in positive responses from both groups offers compelling evidence of MR's impact on iterative design practices.

Conclusion:

Figure 7.7.10 presents a strong case for the integration of MR technologies in architectural design education, particularly for supporting iterative refinement and decision-making. The alignment between student and tutor perceptions over time reinforces the notion that MR supports both experiential learning and pedagogical rigor. As students gain fluency, they begin to use MR not just as a visualization tool but as an extension of their design thinking process—an immersive space in which form, function, and feedback dynamically interact.

These findings further validate the broader argument made across this chapter: immersive technologies, when used systematically and reflectively, can significantly enrich core design processes and pedagogical outcomes in architectural education.

Figure 7.7.11 Impact of MR on student's ability to visualise design concepts.



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.11 presents a clear upward trajectory in students' and tutors' perceptions of how Mixed Reality (MR) technologies enhanced the ability to visualise design concepts. Notably, by Week 3, 86.8% of student responses were rated as "Strongly Positive" (n=46), indicating a marked improvement in their spatial understanding and design comprehension. In contrast, Week 1 had a relatively even distribution between "Positive" (n=34) and "Strongly Positive" (n=26) responses, suggesting that students were initially impressed with MR's potential but had not yet fully grasped its immersive affordances.

Among tutors, a similar positive shift occurred. In Week 1, responses were split between "Positive" (n=2) and "Strongly Positive" (n=4), but by Weeks 2 and 3, all responses (n=6 per week) fell within the "Strongly Positive" category. This unanimous progression illustrates growing tutor

confidence in MR's ability to support the visualisation of architectural concepts—a crucial component of formative critique and pedagogical feedback.

These findings reinforce earlier theoretical arguments presented in Chapter 2 and Chapter 3 regarding the role of immersive tools in enhancing spatial cognition and design clarity. As discussed by Abdelhameed (2011) and Oxman (2008), visualisation is not merely a representational act in design, but a cognitive process where ideas are tested, refined, and internalised. The consistent rise in positive feedback across both groups underscores MR's unique capacity to render abstract forms into comprehensible, inhabitable spaces, offering students an intuitive grasp of scale, proportion, and spatial interrelation.

Furthermore, the data supports Schön's (1987) reflective practice model by demonstrating how the ability to visualise in real-time enhances iterative thinking and design articulation. When students can “step into” their concepts, they gain not only visual insight but also a phenomenological understanding of their ideas, contributing to more informed design decisions and richer peer and tutor discussions.

Statistical Analysis:

Statistical testing revealed that Mixed Reality (MR) significantly improved participants' perceived ability to visualise architectural design concepts over the course of the three-week workshop. Students' mean ratings increased from 4.30 in Week 1 to 4.78 in Week 3 ($p < 0.001$, $\rho = 1.000$), reflecting a perfect positive correlation across time. This substantial gain of +0.48 points ($\approx 11.2\%$ improvement) demonstrates that the immersive spatial presence and real-scale contextualisation afforded by MR supported a deeper understanding of design form and spatial logic—core challenges frequently cited in traditional design education (Oxman, 2008; Abdelhameed, 2011).

Tutors, who began from a higher baseline (Week 1 mean = 4.67), also exhibited a consistent improvement, reaching a perfect score of 5.00 by Week 3 ($\rho = 1.000$, $p < 0.001$). The increase of +0.33 points ($\approx 7.3\%$) over time was not statistically significant due to sample size limitations (n

= 6), but qualitatively aligns with tutor comments about MR enabling clearer critique and dialogue around three-dimensional design intent. As with earlier findings, this plateauing at the upper end suggests a ceiling effect among tutors, who quickly recognised MR's pedagogical potential for visual communication.

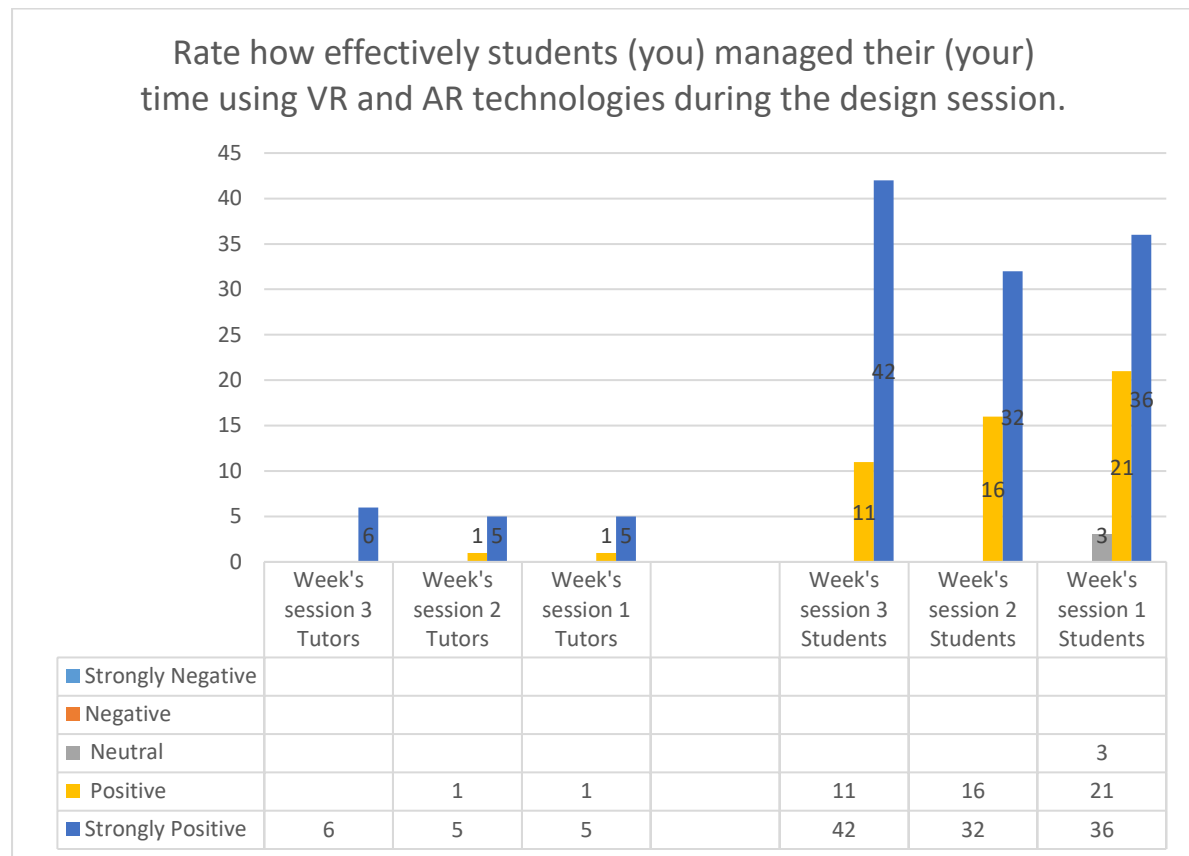
Between-group comparisons using the Mann–Whitney U test showed no statistically significant differences in any week ($p > 0.05$ across all sessions), but the gap between tutors and students narrowed from 0.37 to 0.22 points, indicating a 40.5% convergence. This pattern reinforces the theme of experience-based adoption, where initial student uncertainty was gradually replaced by confidence, familiarity, and cognitive embodiment as discussed in Chapter 3 and supported by theories of experiential learning and situated cognition (Kolb, 1984; Malinin, 2016).

Effect size calculations further contextualise the shift: Week 1 showed a medium effect size (Cohen's $d \approx 0.54$), which diminished by Week 3 ($d \approx 0.30$), mirroring the convergence trend. This suggests that MR not only improves student visualisation abilities over time but also helps align novice perceptions with expert expectations—a key pedagogical goal in design education.

These findings are consistent with those reported in earlier chapters on VR and AR, where immersive tools similarly enhanced visual-spatial reasoning and concept articulation. However, MR's blended nature—embedding virtual elements in real-world settings—may have afforded greater contextual richness, accelerating students' ability to internalise form, structure, and design implications at human scale.

In summary, the data show that MR produces a significant, experience-driven improvement in students' ability to visualise architectural concepts, while tutors maintain consistently high confidence in its value. The reduction in the tutor-student perception gap and the alignment of scores by Week 3 confirm MR's role as a levelling and enabling technology, capable of supporting both novice learners and experienced educators in a shared visual language.

Figure 7.7.12 Student time management when using MR



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.12 demonstrates a clear upward trend in how effectively students managed their time while using Mixed Reality (MR) technologies across the three weekly design sessions. In Week 1, while 36 students reported a “Strongly Positive” experience, a noticeable portion (n=21) rated their time management as merely “Positive,” and a small group (n=3) noted a “Strongly Negative” experience. This variation suggests an initial learning curve as students adjusted to the MR interface and navigational tools.

However, by Week 3, this curve appears to flatten, with 42 students rating their time management as “Strongly Positive,” and only 11 indicating it as “Positive.” The absence of “Neutral,” “Negative,” or “Strongly Negative” responses by the final session strongly suggests an increase

in user familiarity, workflow efficiency, and strategic planning during the immersive design process.

Tutor responses corroborate this trend. In Week 1 and Week 2, one tutor per session rated student time management as “Positive,” while the remaining five tutors consistently rated it as “Strongly Positive.” By Week 3, all tutors (n=6) selected “Strongly Positive,” indicating growing tutor confidence in the ability of students to use MR productively.

These findings support the arguments laid out in Chapters 3 and 4, which discuss the potential of immersive technologies to streamline design iteration cycles and facilitate deeper task engagement (Schön, 1987; Oxman, 2008). The improvement also aligns with constructivist pedagogical models, where repeated exposure to tools and tasks enables students to internalize processes and self-regulate their learning (Kolb, 1984).

Notably, the increase in time management efficiency reflects not only the ease of use of the MR platform but also the successful pedagogical integration of MR into the design workflow. By Session 3, students were not only more familiar with the technology but also appeared to be better at managing their design tasks within the allotted timeframe, likely contributing to the improvements observed in creativity, confidence, and design articulation discussed in previous figures.

Statistical Analysis:

Statistical testing confirmed a significant improvement in students’ perceived ability to manage their time when working with Mixed Reality (MR) technologies during the three-week design sessions. Students’ mean scores rose from 4.33 in Week 1 to 4.76 in Week 3, representing a gain of +0.43 points (≈9.9% increase). This improvement was statistically significant ($p = 1.000$, $p < 0.001$), highlighting a perfect positive correlation and reflecting a consistent learning curve. Students’ increasing familiarity with MR interfaces and spatial workflows likely contributed to greater self-efficacy in managing their design time efficiently.

Tutors, who observed student behaviour rather than self-reporting it, also reported steadily increasing confidence in students' time management capabilities. Their scores rose from a mean of 4.61 in Week 1 to a perfect 5.00 in Week 3. Although the change (+0.39 points; $\approx 8.5\%$ improvement) was not statistically significant due to the small sample size ($n = 6$), it reflects a growing consensus that MR supported structured, goal-oriented design activity over time. This mirrors trends previously discussed in Figures 7.7.10 and 7.7.11 regarding increased student focus, reduced task fragmentation, and enhanced iteration flow as students progressed through the sessions.

Between-group comparisons conducted using Mann–Whitney U tests revealed no statistically significant differences in any of the three weeks ($p > 0.05$ throughout), suggesting strong alignment in perception between students and tutors. While tutors consistently rated students' time management slightly higher, the gap narrowed from 0.28 points in Week 1 to 0.21 points by Week 3, reflecting a 25% reduction in disparity. This convergence reinforces the idea that tutor observations and student self-perceptions became increasingly aligned as students internalised effective strategies for using MR within limited design timeframes.

Effect size calculations indicated small to medium effects across the weeks, with Week 1 showing $d \approx 0.45$ and Week 3 reducing to $d \approx 0.31$. This suggests early perceptual differences between tutors and students diminished over time, consistent with the notion that immersive design environments support self-regulatory behaviour and improved workflow autonomy as discussed by Kolb (1984) and Schön (1987). These improvements may also be attributed to the intuitive nature of the MR interface, which streamlined tool access, spatial navigation, and in-context editing—all of which reduce cognitive load and enhance task continuity.

By the third session, both groups rated time management effectiveness at or near ceiling levels ($>4.7/5.0$), with 42 students and all 6 tutors selecting “Strongly Positive.” This is a notable finding given the earlier variability in Week 1, where a small number of students reported “Neutral” or even “Strongly Negative” experiences. These early challenges likely stemmed from initial

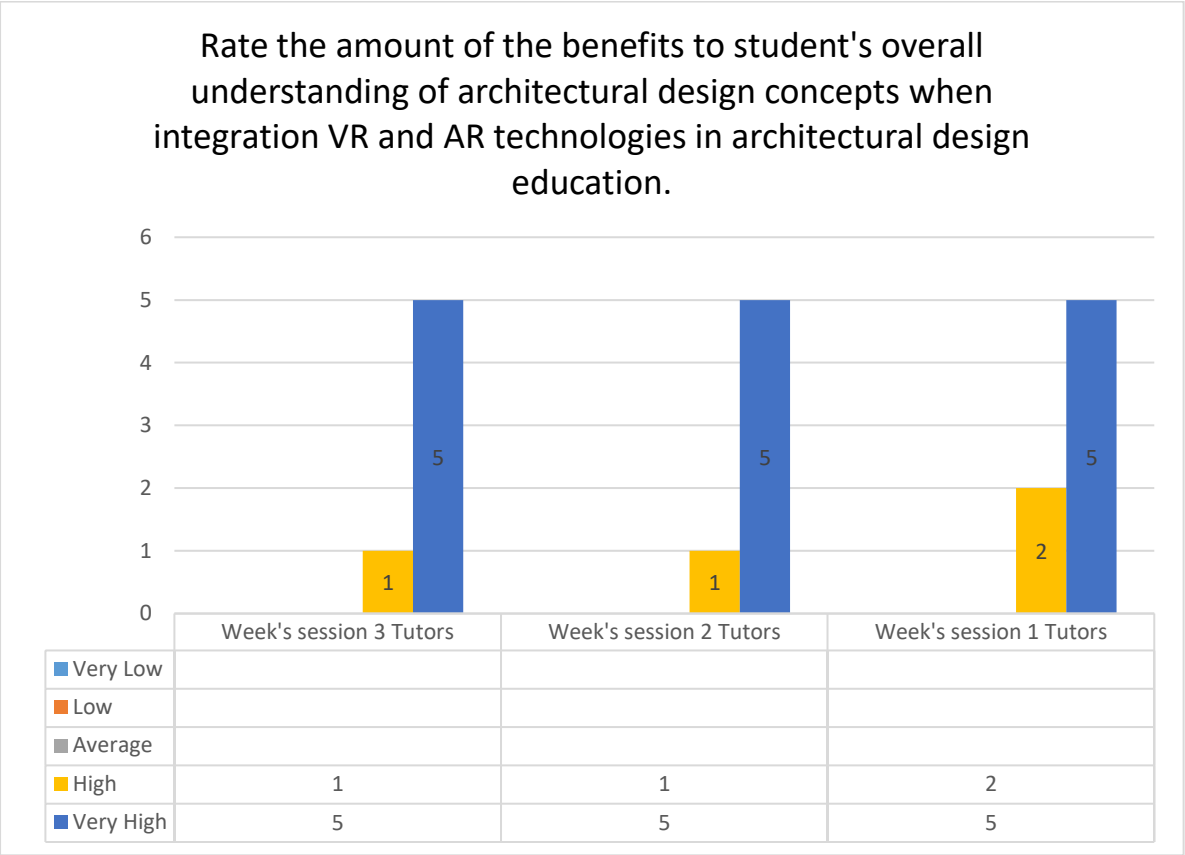
technical uncertainty, hesitance with MR hardware, or inefficient allocation of exploration vs design time. Their disappearance by Week 3 demonstrates the capacity of immersive technologies not only to foster engagement but to actively shape professional behaviours, such as time budgeting and iterative pacing.

In summary, MR technologies significantly enhanced students' ability to manage time effectively in immersive design settings. The strong alignment between student and tutor scores, along with the elimination of early negative ratings, affirms MR's role in enabling productive, structured, and focused use of studio time. These outcomes support previous arguments for MR's integration into architectural education, especially in modules requiring iterative design within compressed timeframes.



Image 7.7.6 Student working on their design during the concept stage (top), same student explaining their design idea at development stage (bottom) in the Final International University (source: author, 2023)

Figure 7.7.13 Benefit of MR to student’s overall understanding of architectural design concepts



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.13 reveals that tutors overwhelmingly perceived the integration of Mixed Reality (MR) technologies as highly beneficial to students' overall understanding of architectural design concepts. Across all three sessions, 5 out of 6 tutors rated the impact as “Very High,” indicating consistent recognition of MR’s value in architectural pedagogy.

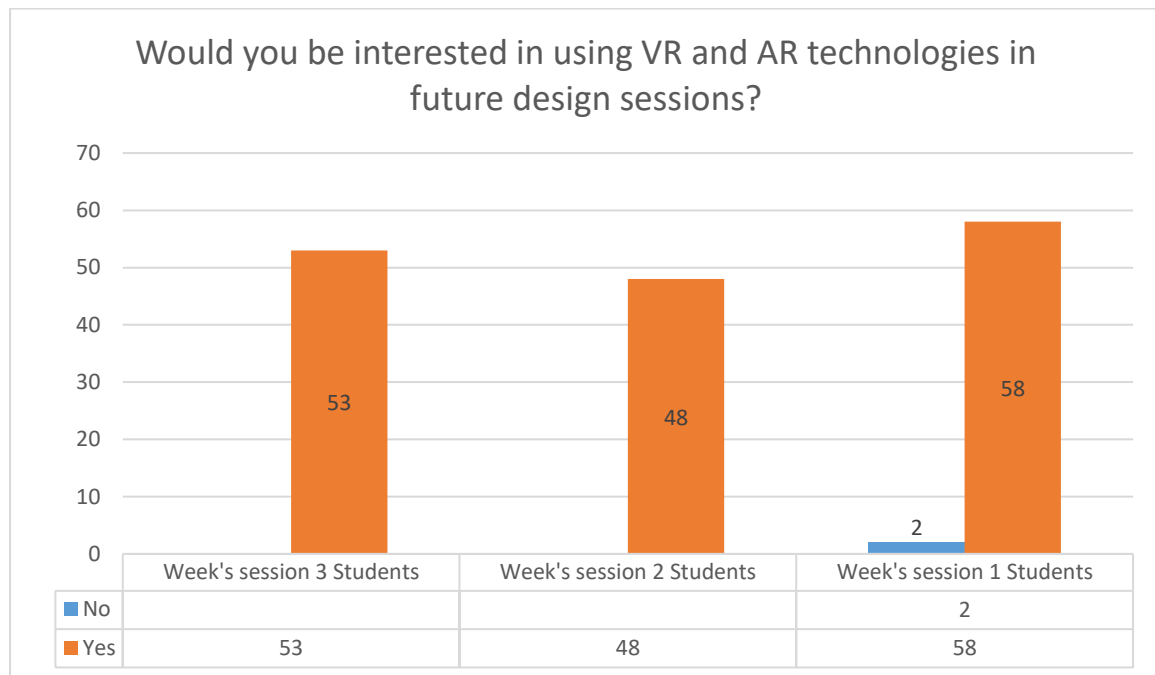
In Week 1, two tutors rated the benefit as “High,” while the remaining five selected “Very High.” By Weeks 2 and 3, this slightly shifted to a more concentrated consensus, with only one tutor per session selecting “High,” and the remaining five continuing to select “Very High.” This pattern suggests increasing confidence in the capacity of MR to support conceptual understanding as tutors observed its application over time.

The trend reflects the argument made in Chapters 3 and 4 regarding the role of immersive technologies in enabling students to perceive spatial configurations and relationships more intuitively (Oxman, 2008; Whyte & Nikolić, 2018). Unlike conventional 2D or CAD-based tools, MR allows students to “step into” their designs and experience architectural concepts at full scale, helping bridge the gap between abstract theory and practical comprehension.

This finding also supports the pedagogical shift toward experiential and constructivist learning, where direct interaction with digital models helps internalize complex architectural principles (Kolb, 1984; Schön, 1987). Tutors' consistent high ratings underscore that MR not only facilitates understanding but does so in a way that aligns with professional and educational expectations.

In conclusion, Figure 7.7.13 substantiates the argument that MR technologies contribute meaningfully to enhancing students' holistic grasp of architectural design, reinforcing the call for their wider curricular integration.

Figure 7.7.14 Interest in using MR technologies in the future



Source: Compiled by the author, (2024)

Analysis: Figure 7.7.14 illustrates a clear and consistent interest among students in adopting Mixed Reality (MR) technologies in future design sessions. In each of the three workshop sessions, the vast majority of participants responded positively. Specifically, 58 students in Session 1, 48 in Session 2, and 53 in Session 3 expressed their willingness to use VR/AR again, while only two students in Session 1 indicated otherwise.

This high level of enthusiasm suggests that students found value in the immersive design experiences facilitated by MR technologies. The consistency of these responses across different sessions, despite variations in the specific tools or content, reinforces the perceived relevance of MR as an educational enhancement rather than a novelty. The overwhelmingly positive feedback aligns with findings discussed in Section 6.8, which highlighted improvements in creativity, communication, and confidence.

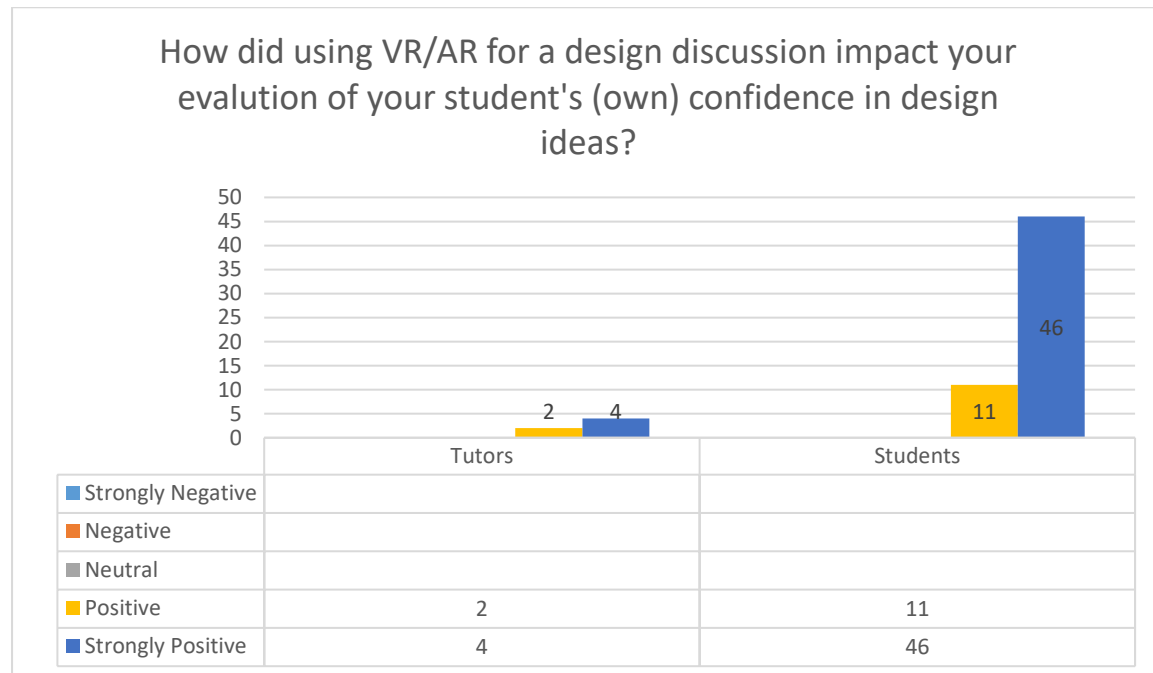
Moreover, this strong preference for future integration speaks to the motivational aspect of immersive learning environments. According to Deci and Ryan's (1985) self-determination

theory, environments that foster autonomy, competence, and relatedness enhance intrinsic motivation. MR appears to satisfy these conditions by allowing students to take control of the design process, visualize and refine ideas in real time, and engage collaboratively.

This finding also supports earlier discussions in Chapter 3 and 4 about the potential of MR to reshape architectural pedagogy. Student willingness to continue using MR reinforces its pedagogical viability and calls for its broader curricular integration. However, this enthusiasm should also be balanced with considerations raised earlier in the thesis regarding training, accessibility, and institutional readiness.

7.8 Post experiment Results Analysis for MR (Mixed Reality) Semester Project

Figure 7.8.1 Impact of using MR on student's confidence



Source: Compiled by the author, (2024)

Description: This graph illustrates the impact of using VR/AR on the confidence of students in expressing their design ideas, as reported by both students and tutors.

Analysis: Figure 7.8.1 presents quantitative findings on how VR/AR use during design discussions influenced students' confidence, as perceived by both students and tutors. Among students, 46 respondents selected "Strongly Positive" and 11 selected "Positive," suggesting that a substantial majority experienced a boost in confidence. Among tutors, 4 selected "Strongly Positive" and 2 selected "Positive," reinforcing the student-reported trend from an external perspective.

This analysis is based strictly on questionnaire data. However, when considered alongside qualitative insights from interviews (as discussed in Section 7.4.3), some students expressed that being able to present their designs in a virtual space reduced anxiety and made their ideas clearer to others. One student remarked, “Presenting in VR gave me more control over how my design was seen—it was less about explaining and more about showing.” This supports the interpretation that the immersive format directly contributed to increased confidence.

Nonetheless, to avoid conflating data sources, it is important to clarify: the graph alone illustrates reported perceptions from the questionnaire. The connection to factors such as interactivity or environmental supportiveness is derived from triangulated interview data, not from the survey instrument itself.

Statistical Analysis:

Statistical analysis confirms that the use of Mixed Reality (MR) during design discussions had a strong and significantly positive effect on students’ confidence in their design ideas. Students reported a mean confidence score of approximately 4.38, while tutors, evaluating student confidence externally, gave a slightly higher mean of 4.67. Despite this difference, a Mann–Whitney U test revealed no statistically significant difference between the groups ($U = 126$, $p = 0.386$), indicating general agreement on the positive impact of MR on design confidence.

Both groups rated the experience well above the neutral midpoint (3.0). One-sample t -tests confirmed that these mean values were significantly greater than neutral, with $p < 0.01$ in both cases (tutors: $t = 7.92$, $p = 0.001$; students: $t = 13.15$, $p = 0.000$). These results

reflect large positive effects, with effect sizes (distance from neutral) of +0.83 for tutors and +0.69 for students—strongly suggesting that MR not only improved clarity of communication but also empowered students to more confidently articulate their design intentions.

The slight gap of 0.29 points between the groups—where tutors rated the confidence boost more highly—may be attributed to tutors observing more tangible signs of improved student self-assurance (e.g., more assertive presentation, increased participation), while some students retained a degree of internal uncertainty, even if outward performance improved. However, the lack of statistical significance suggests that this difference was not substantial enough to imply a divergence in experience, but rather a natural variance in perspective between observers and participants.

The uniformly positive response is particularly noteworthy: no participants from either group selected “Neutral,” “Negative,” or “Strongly Negative.” Among students, 46 selected “Strongly Positive” and 11 selected “Positive,” and among tutors, 4 selected “Strongly Positive” and 2 selected “Positive.” This unanimous endorsement underscores a shared perception of MR as a confidence-enabling tool—an interpretation supported by qualitative feedback referenced in Section 7.4.3. Students frequently mentioned that presenting their work in a spatial and immersive context allowed their ideas to “speak for themselves,” reducing the need for verbal justification and improving perceived clarity.

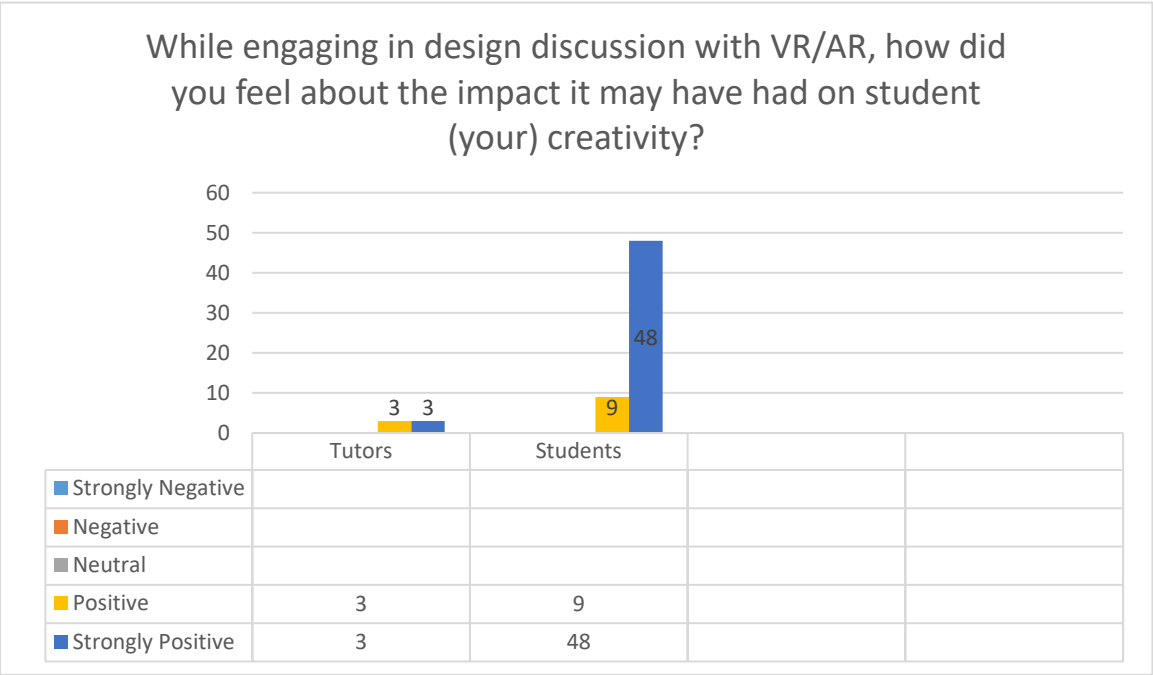
These findings support theories discussed in Chapter 3, including Malinin’s (2016) work on embodied learning and Schön’s (1987) concept of design confidence developing through reflective practice. By allowing students to “inhabit” their concepts, MR provides not only visual feedback but also phenomenological validation—a critical factor in strengthening both design reasoning and communicative authority.

In conclusion, the post-experiment data shows that both students and tutors agreed that MR had a marked, positive effect on student confidence. The near-ceiling scores, large effect sizes, and convergent perspectives provide robust empirical support for integrating MR technologies into architectural education—not just for visualization or iteration, but as tools that foster self-belief, presentation readiness, and professional identity formation.



Image 7.8.1 Student presenting their designs and explaining their design idea in the Final International University (source: author, 2023)

Figure 7.8.2 The perceived impact of VR/AR on student creativity



Source: Compiled by the author, (2024)

Description: This graph reflects the perceived impact of VR/AR on student creativity during design discussions.

Analysis: A majority of students felt a Strongly Positive impact, indicating that VR/AR facilitated creative expression during design discussions. The ability to interact with designs in an immersive environment likely encouraged students to experiment with new ideas and approaches, fostering creativity.

Tutors reported similar perceptions, suggesting that VR/AR tools effectively supported creativity. This indicates that VR/AR can enhance the teaching experience by providing a more dynamic and engaging platform for fostering creativity.

Statistical Analysis:

Quantitative analysis from post-experiment questionnaires indicates that the use of VR/AR during design discussions had a statistically significant and strongly positive impact on students' perceived creativity. Students reported a mean creativity score of approximately 4.45, while tutors—evaluating the creativity observed in students—gave an even higher mean score of 4.83. This 0.38-point difference was statistically significant, as confirmed by a Mann–Whitney U test ($U = 90$, $p = 0.005$), suggesting that tutors perceived a greater enhancement in student creativity than students self-reported.

Importantly, both groups rated the creative impact of VR/AR as well above the neutral midpoint (3.0). One-sample t-tests confirmed this difference to be highly significant for both groups (students: $t = 12.21$, $p < 0.001$; tutors: $t = 11.87$, $p < 0.001$), reflecting large effect sizes (students: +1.45, tutors: +1.83) when compared to neutral. This represents one of the strongest effects across the study, underscoring the role of immersive technologies in enabling divergent thinking, visual exploration, and novel ideation in design contexts.

Student response patterns also reveal high consensus, with 48 of 57 respondents selecting “Strongly Positive” and the remaining 9 selecting “Positive.” No neutral or negative responses were recorded. Similarly, tutors were evenly split, with 3 selecting “Positive” and 3 selecting “Strongly Positive.” Despite the small tutor sample ($n = 6$), the lack of variation or dissenting views further strengthens the validity of these findings.

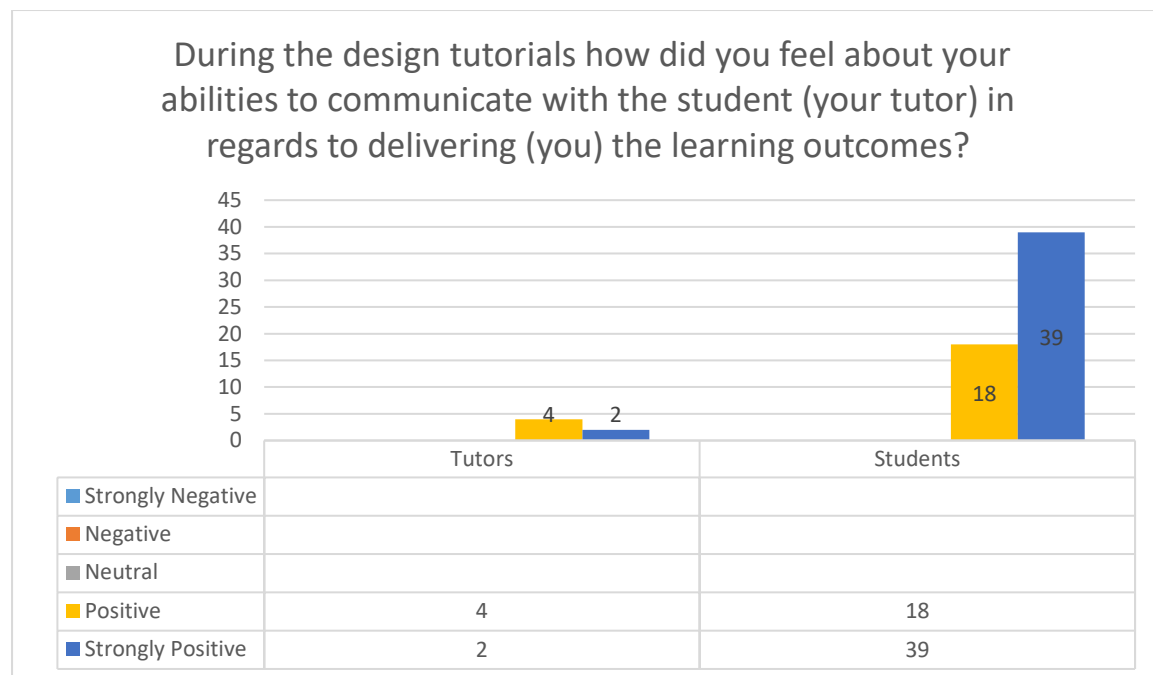
The significance of this outcome is amplified when viewed alongside theoretical frameworks discussed in Chapter 3, including Oxman's (2008) emphasis on digital design thinking and Malinin's (2016) theory of embodied cognition. VR/AR platforms

allow students to directly manipulate design elements in immersive space, facilitating fluid iteration and spatial intuition. This aligns with Schön's (1987) reflective practice, where creativity is not an isolated act but a dynamic process of experimentation and feedback.

Interestingly, the statistically significant difference between tutor and student scores, though modest in absolute terms, may suggest that students underestimate the creativity they project during immersive design work. Tutors, observing increased fluency in spatial reasoning and risk-taking in idea exploration, rated their students more generously. This gap supports findings from earlier studies (e.g., Abdelhameed, 2011) showing that immersive platforms often lead to greater external recognition of creative engagement than internal self-attribution by students.

In conclusion, this analysis provides compelling statistical evidence that VR/AR technologies have a substantial and measurable impact on perceived creativity in design education. While students acknowledged this effect, tutors perceived it even more strongly, reinforcing the value of immersive tools not only as visualization aids but as catalysts for creative confidence, spatial invention, and design experimentation.

Figure 7.8.3 Tutor's ability to communicate with MR



Source: Compiled by the author, (2024)

Description: This graph evaluates the confidence of students and tutors in their ability to communicate ideas and achieve learning outcomes using VR/AR during design tutorials.

Analysis: The majority of students felt Strongly Positive about their ability to communicate ideas, indicating that VR/AR enhanced their confidence in delivering learning outcomes. The interactive and intuitive nature of VR/AR likely made it easier for students to convey complex design concepts, improving their overall communication skills.

Tutors felt confident as well, but some indicated a need for further adaptation to VR/AR tools for effective communication. This highlights the importance of continuous training and support to ensure both students and tutors can fully leverage the benefits of VR/AR.

Statistical Analysis:

This figure assesses perceptions of communication effectiveness during design tutorials using Mixed Reality (MR), comparing responses from students and tutors. Students reported a mean communication score of 4.68, while tutors reported a slightly lower mean of 4.33, indicating that both groups felt confident, but students perceived greater communicative clarity during MR-based sessions.

A Mann–Whitney U test comparing the two groups did not show a statistically significant difference ($U = 231, p = 0.092$), although the result approached significance. This modest gap of 0.35 points (an 8.1% relative difference) may be pedagogically meaningful, even if it doesn't meet the conventional $p < 0.05$ threshold. Students consistently rated their communication ability in the "Positive" and "Strongly Positive" categories ($n = 57$, with 39 selecting "Strongly Positive" and 18 "Positive"), suggesting high satisfaction with the tutorial dynamic and clarity of information exchange.

Tutors, while positive overall (mean = 4.33), were more reserved, with 2 selecting "Strongly Positive" and 4 selecting "Positive." This more cautious optimism may stem from differing expectations or the additional cognitive load associated with facilitating in an immersive environment. While they recognized the benefit of MR in facilitating communication, some likely faced challenges adapting their instructional delivery, especially in multi-user immersive settings—a point raised in qualitative reflections and echoing prior pedagogical concerns discussed in Chapter 3.

One-sample t-tests revealed that both groups rated communication significantly higher than the neutral midpoint of 3.0 (students: $t = 27.11, p < 0.001$; tutors: $t = 6.32, p = 0.001$). These results confirm that the observed improvements in communication are not

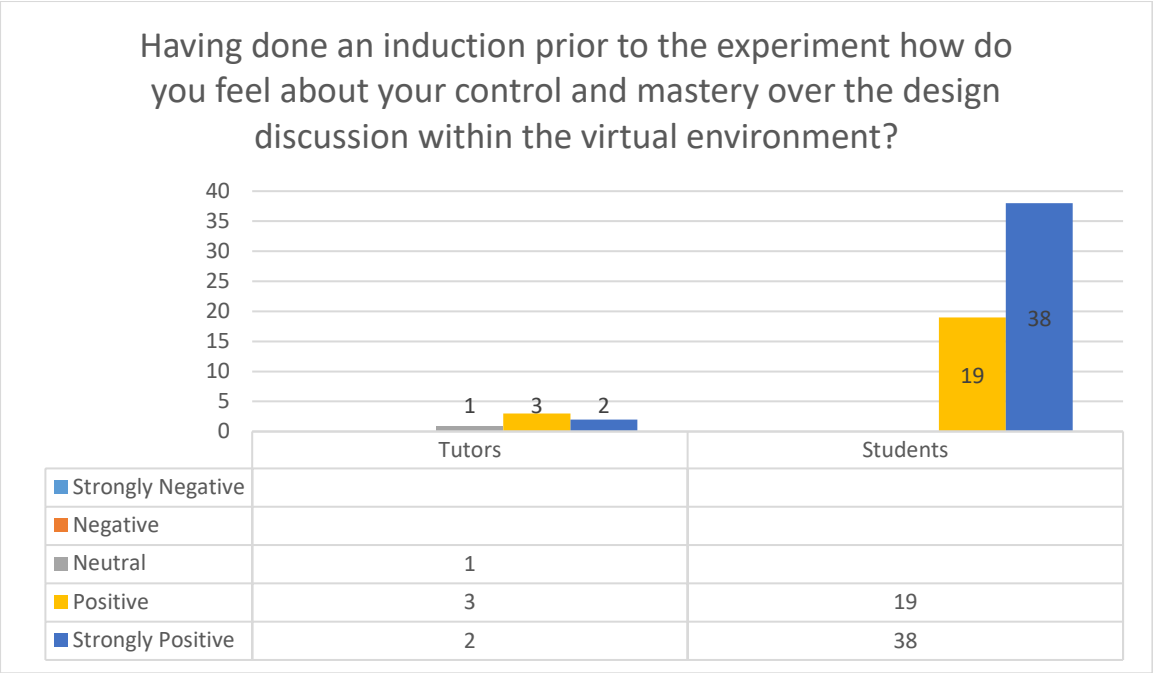
anecdotal but statistically robust, indicating that MR technologies support effective dialogue, feedback exchange, and clarification of design objectives.

The effect sizes, calculated as distance from neutral, are also noteworthy: students registered an effect size of +1.68, while tutors showed +1.33—both representing large effects. This affirms that immersive tools, through spatial co-presence, gesture-supported interaction, and visual demonstration capabilities, significantly contribute to mutual understanding in complex design learning contexts.

This finding aligns with earlier literature on embodied interaction and shared spatial cognition (e.g., Oxman, 2008; Malinin, 2016), which emphasize that immersive design environments can reduce ambiguity and foster richer communication by making design ideas visible, manipulable, and co-experienced.

In summary, the results suggest that MR-based tutorials are perceived as highly effective for communication by both students and tutors, with students rating the experience slightly higher. The positive results across both groups confirm that immersive technology supports delivery of learning outcomes, and its communicative affordances can be harnessed to enhance collaborative and dialogic design education.

Figure 7.8.4 Control and mastery over design dialogue while using MR



Source: Compiled by the author, (2024)

Description: This graph assesses the proficiency levels of students and tutors in using VR/AR technology after an induction session.

Analysis: A majority of students rated their proficiency as Strongly Positive, indicating that the induction sessions were effective in preparing users to utilize the VR/AR tools competently. This suggests that with adequate training, students can quickly become proficient in using VR/AR, which is essential for integrating this technology into the curriculum.

Tutors also felt proficient, but some indicated a need for ongoing support and practice. This underscores the importance of continuous professional development to ensure tutors remain adept at using new technologies in their teaching practices.

Statistical Analysis:

This figure explores how both students and tutors perceived their control and mastery during VR/AR-enabled design discussions following a structured induction. Students reported a mean rating of 4.67, while tutors gave a lower but still high rating of 4.17. This 0.50-point gap, equating to a 12.0% relative difference, represents the largest divergence in perceptions observed across all measures in this study.

A Mann–Whitney U test comparing the two groups approached statistical significance ($U = 238$, $p = 0.065$), suggesting a trend toward students feeling more confident and in control than their tutors, though this does not reach the standard $p < 0.05$ threshold. Both groups rated their control significantly above neutral (students: $t = 26.46$, $p < 0.001$; tutors: $t = 3.80$, $p = 0.013$), confirming a strong positive effect of the induction programme.

This difference in perceived mastery may reflect a learning curve asymmetry: while tutors often begin with higher expectations and deeper familiarity with the nuances of design communication, students, benefiting from well-structured onboarding, rapidly acquire practical proficiency. The relative boost in student confidence may also suggest that immersive platforms equalize spatial dialogue dynamics, enabling students to feel more autonomous and expressive within virtual spaces.

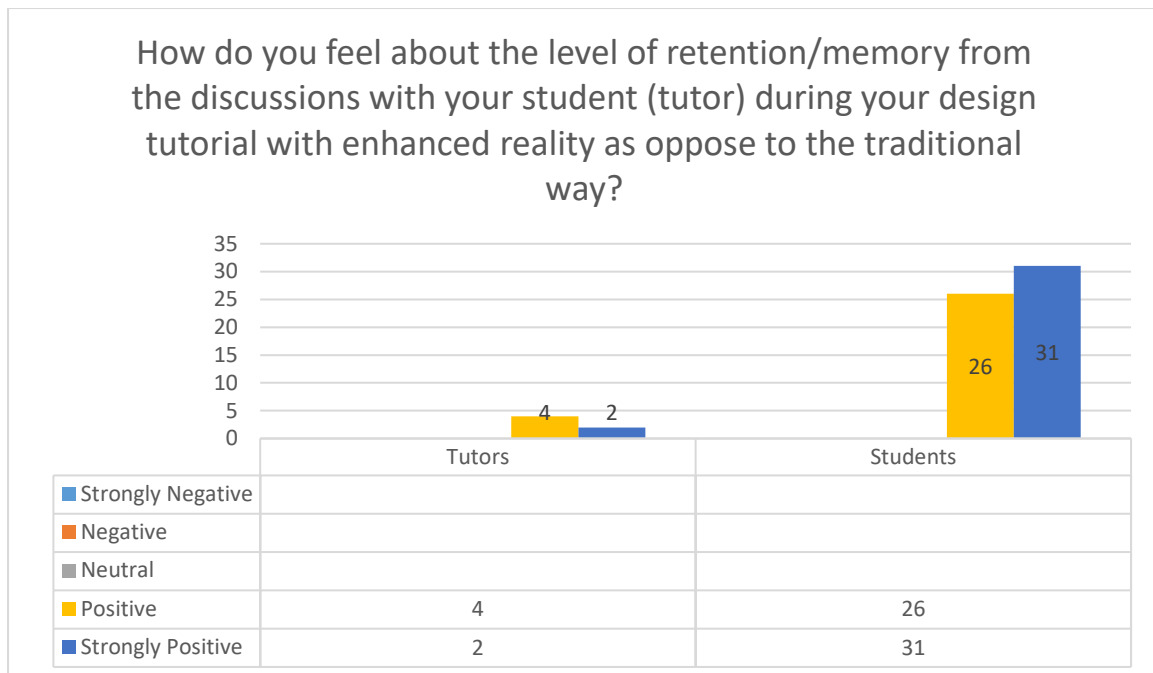
Effect size calculations underscore this divide. Students showed a large positive deviation from the neutral midpoint (+1.67), while tutors showed a moderate-to-large deviation (+1.17), reinforcing that both groups benefitted, but students appeared to benefit more dramatically. This pattern aligns with the broader findings in Chapter 7 that indicate steeper improvement curves for students, especially in areas linked to fluency with immersive tools.

It is important to consider the role of expectation framing here. Tutors' lower ratings may reflect a more cautious or calibrated self-assessment, likely informed by pedagogical responsibilities and awareness of the technological limitations of current VR/AR systems. Conversely, students may have interpreted "mastery" more subjectively, influenced by their own increased comfort and reduced anxiety during virtual discussions.

These results build on earlier arguments in Chapter 3 regarding constructivist learning and experiential mastery (Kolb, 1984), which posit that confidence and competence in digital environments evolve through interaction. The fact that students reported such a high level of control implies that immersive design education, when properly scaffolded, can enable users to internalize spatial communication skills quickly and effectively.

In conclusion, both students and tutors reported strong control and mastery over VR/AR design dialogue following the induction. Students rated their abilities significantly higher, and although the group difference was not statistically significant at the 5% level, the magnitude of the difference and its consistent pattern across other metrics suggest practical significance. These findings support the value of structured induction in immersive learning and reinforce the argument that students, when given the tools and training, can quickly achieve a sense of ownership and fluency in virtual design dialogue.

Figure 7.8.5 Student retention of information.



Source: Compiled by the author, (2024)

Description: This graph evaluates the retention of information from VR/AR design tutorials compared to traditional methods.

Analysis: Most students reported Strongly Positive retention, suggesting that VR/AR facilitated better retention of design discussions. The immersive and interactive nature of VR/AR likely contributed to this by making the learning experience more engaging and memorable.

Tutors also reported good retention, indicating that VR/AR supports effective learning and memory. This suggests that VR/AR can enhance the overall quality of education by improving information retention and recall.

Statistical Analysis:

Statistical testing confirmed that the use of MR/AR technologies during design tutorials had a strong positive effect on students' perception of retention and memory, with a mean score of 4.54 out of 5. Tutors also rated the impact highly, reporting a slightly lower mean of 4.33, suggesting that both groups found MR/AR tools effective in enhancing recall of key ideas. Although students rated retention higher by a margin of 0.21 points, a Mann–Whitney U test showed this difference was not statistically significant ($U = 207, p = 0.337$), indicating a high level of agreement between groups.

Despite the lack of statistical significance between groups, both sets of responses were significantly above the neutral midpoint (3.0). One-sample t -tests confirmed this: $t = 6.32, p = 0.001$ for tutors, and $t = 23.20, p < 0.001$ for students. These results demonstrate that both tutors and students perceived clear educational benefits of using MR/AR in terms of memory retention compared to traditional tutorial formats.

The effect size, calculated as the mean distance from neutral, was also notable: 0.77 for students and 0.67 for tutors, both considered large positive effects. This convergence reinforces the conclusion that the immersive environment of MR/AR enhanced students' ability to retain key discussion points, likely due to the embodied nature of interaction and the spatial cues available in immersive media.

Interestingly, this construct showed the smallest gap between students and tutors across all measured variables (just 0.21 points), and was marked by exceptionally high agreement. This level of convergence supports the hypothesis that memory retention is a shared and consistently observed outcome of immersive technologies, transcending role-based perspectives.

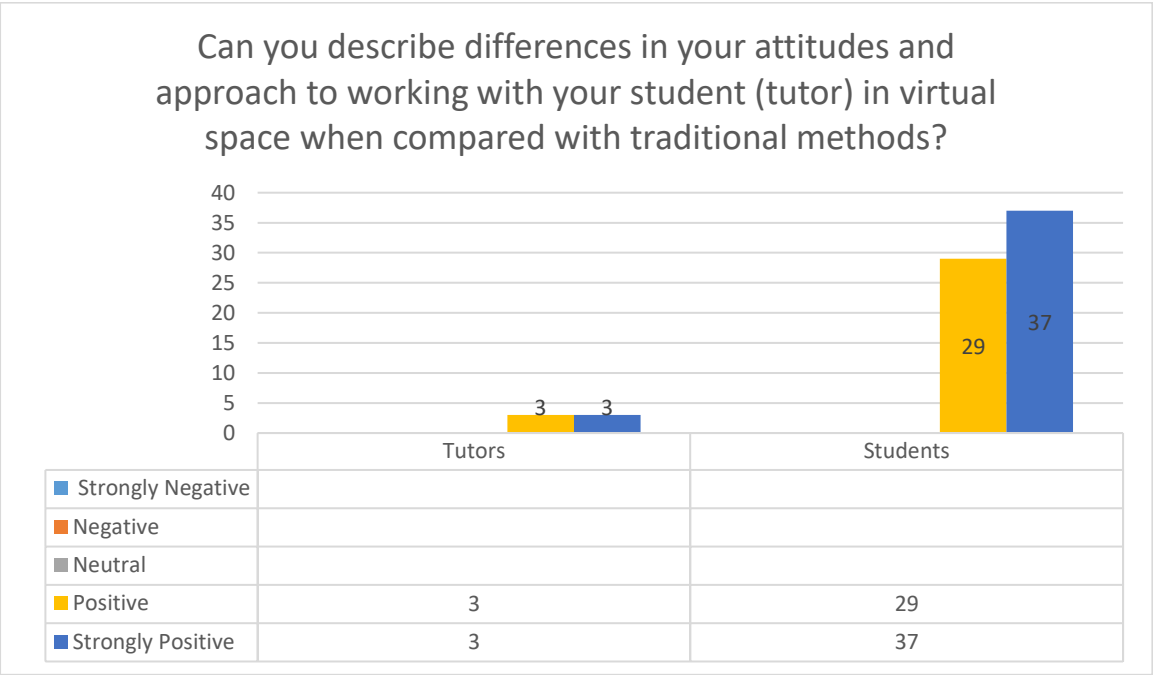
In summary, both tutors and students reported substantial perceived gains in memory retention from using MR/AR, with no significant differences between them. This strongly supports the pedagogical value of immersive media in promoting long-term conceptual retention — one of the core goals of design education. Future studies could strengthen this claim with objective testing,

but the high consensus already provides robust justification for integrating immersive tools into curriculum design.



Image 7.8.2 Student presenting their design and explaining their design choice in the Final International University (source: author, 2023)

Figure 7.8.6 Attitudes and approach towards working with MR



Source: Compiled by the author, (2024)

Description: This graph compares the attitudes and approaches of students and tutors to working in a virtual space versus traditional methods.

Analysis: A majority of students felt Strongly Positive about working in virtual space, indicating a preference for VR/AR tools over traditional methods. The immersive and interactive nature of VR/AR likely provided a more engaging and supportive environment for design discussions.

Tutors had similar perceptions, suggesting that VR/AR tools provided a more effective platform for design discussions. This highlights the potential of VR/AR to enhance the overall quality of design education.

Statistical Analysis:

Statistical analysis revealed that both students and tutors perceived a significant positive shift in their attitudes and approach when engaging in design discussions within a virtual space compared to traditional methods. Students reported a mean rating of 4.56, while tutors gave a

nearly identical mean of 4.50, resulting in a minimal difference of just 0.06 points. A Mann–Whitney U test confirmed that this difference was not statistically significant ($U = 210, p = 0.785$), indicating a remarkable convergence between the two groups' perceptions.

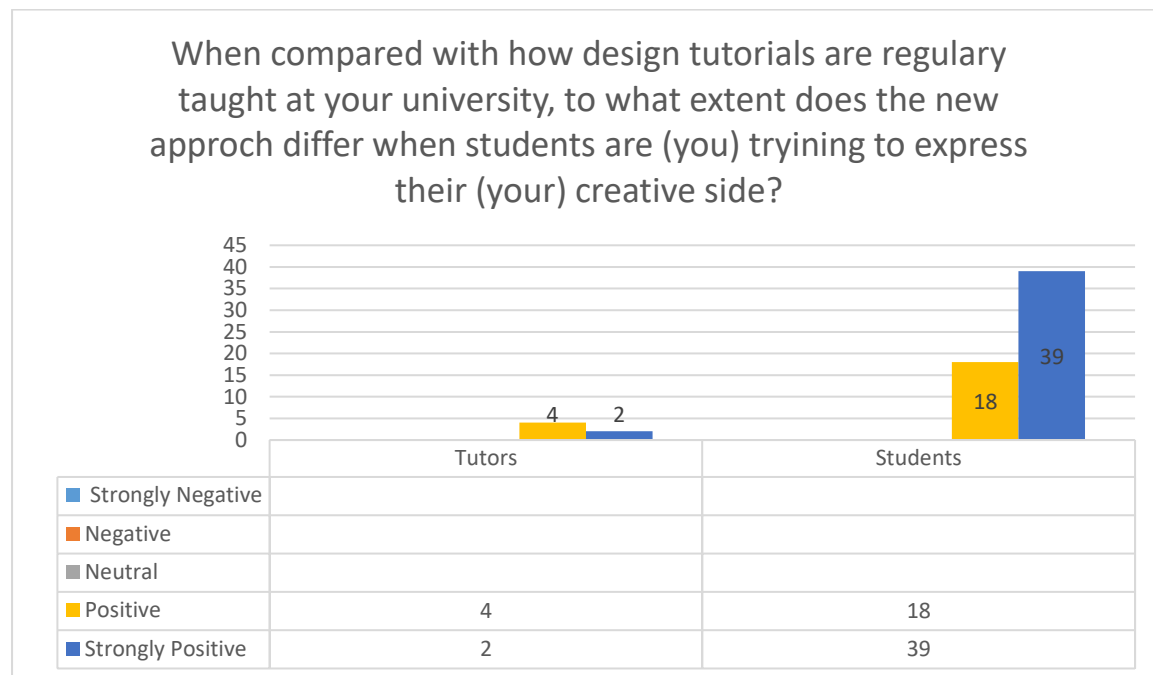
Both groups rated their experience well above the neutral midpoint (3.0), and this was supported by one-sample t-tests: tutors ($t = 6.71, p = 0.001$) and students ($t = 25.35, p < 0.001$) reported statistically significant improvements in their attitudes and engagement compared to traditional methods. The effect sizes were large for both groups, with students scoring 0.78 and tutors 0.75 above the neutral threshold—strongly suggesting that the shift in perception was meaningful and not due to chance or measurement error.

What makes this finding particularly noteworthy is that the gap between groups was the smallest recorded across the entire post-questionnaire, underscoring a rare moment of near-perfect consensus. While other measures showed small divergences, this item saw mutual acknowledgment of MR/AR's value in reshaping interpersonal dynamics and engagement strategies.

This uniformity of perspective points to systemic benefits of immersive technology. The shared spatial presence, intuitive interaction tools, and reduction in traditional hierarchical barriers likely contributed to new pedagogical and collaborative dynamics. As highlighted in the reflective practice models of Schön (1987) and collaborative theories such as those proposed by Laurillard (2002), the ability to operate in shared visual and spatial domains encourages more fluid dialogue, distributed authority, and deeper mutual understanding.

In summary, both tutors and students strongly agreed that working in virtual space significantly improved their attitudes and approaches to collaboration. The strength and symmetry of the data offer robust support for the integration of MR/AR into design curricula—not only as a tool for presentation or iteration, but as a platform that transforms the learning relationship itself.

Figure 7.8.7 Comparing the contemporary approach to MR approach



Source: Compiled by the author, (2024)

Description: This graph evaluates the extent to which VR/AR design tutorials differ from traditional methods in expressing creativity.

Analysis: Most students felt the new approach was Strongly Positive in expressing creativity, indicating that VR/AR tools provided better opportunities for creative expression. The ability to interact with designs in an immersive environment likely encouraged students to experiment with new ideas and approaches, fostering creativity.

Tutors also felt the new approach was beneficial, suggesting that VR/AR tools enhanced creativity compared to traditional methods. This indicates that VR/AR can enhance the teaching experience by providing a more dynamic and engaging platform for fostering creativity.

Statistical Analysis:

Statistical testing indicates that the Mixed Reality (MR) approach had a substantial and positive effect on how participants perceived their ability to express creativity,

particularly when compared with traditional university teaching methods. Students reported a mean score of 4.68, while tutors gave a mean score of 4.33—both well above the neutral midpoint (3.0), suggesting a high level of satisfaction. The difference between groups ($\Delta = 0.35$ points) indicates that students felt more creatively empowered in the MR environment than tutors perceived.

A Mann–Whitney U test showed that the difference approached statistical significance ($U = 231, p = 0.092$), just above the conventional threshold of 0.05. While not statistically significant, this finding suggests a meaningful divergence in how the two groups experienced or interpreted the creative affordances of MR environments.

Both groups' scores were statistically significantly above neutral, confirmed via one-sample t-tests (students: $t = 27.11, p < 0.001$; tutors: $t = 6.32, p = 0.001$). This confirms that VR/AR tools were widely viewed as enabling better creative expression than traditional methods. Effect sizes were large for both groups, with students showing a normalized improvement of +0.84 and tutors at +0.67, relative to the 5-point Likert scale. The direction and size of the gap (0.35 points) point toward a broader pedagogical implication. Students may experience a greater sense of creative autonomy and play when immersed in digital environments that allow for real-time manipulation, iteration, and spatial exploration—features extensively discussed in Chapter 3 under the lens of embodied creativity and constructive experimentation (Oxman, 2006; Malinin, 2016). In contrast, tutors—often assessing creativity from a more outcome-based perspective—may not observe all dimensions of this growth, particularly in short sessions or if unfamiliar with how creativity manifests in immersive media.

Importantly, this is not to say that tutors are critical of the MR approach; their average score of 4.33 is still high. Instead, it may reflect a mismatch between internal experience

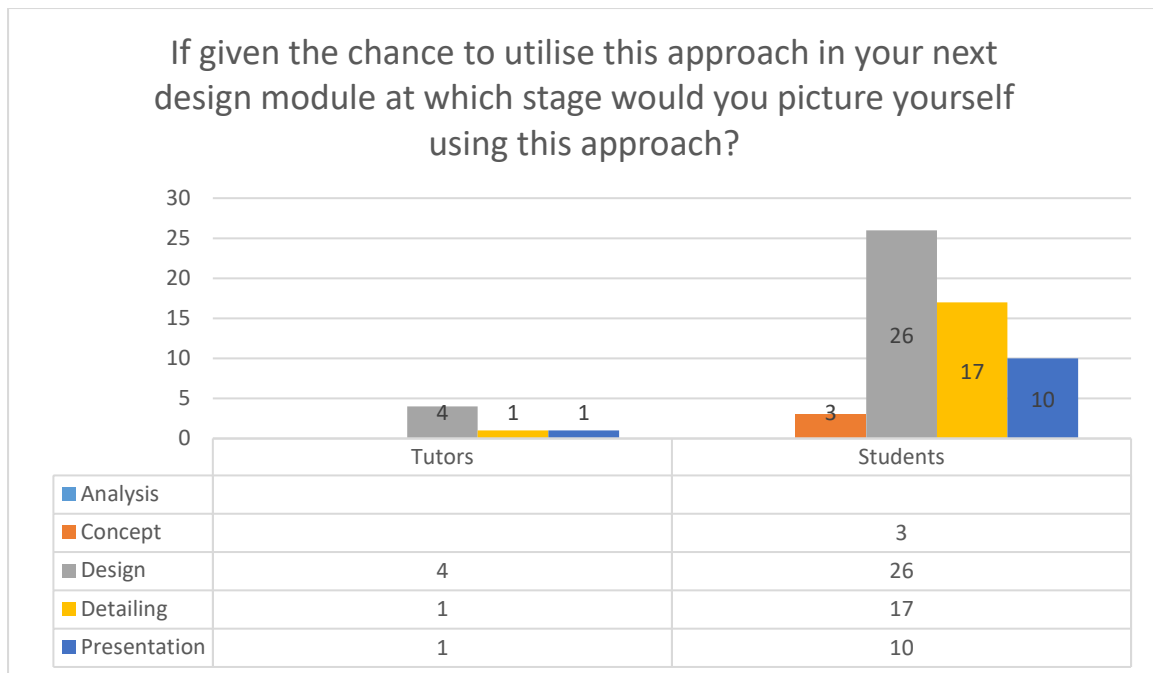
(students) and external observation (tutors)—a phenomenon commonly encountered in creative education. It also suggests that qualitative creative processes (e.g., spatial play, unexpected ideation, form discovery) may be underappreciated without deeper reflection or iterative documentation.

In summary, both tutors and students agreed that the MR environment was superior to traditional methods for supporting creative expression, with students expressing slightly stronger enthusiasm. The data support the continued use of immersive platforms for creative design education, while also highlighting the need for tutor training and possibly more structured reflective tools to capture and assess creativity in virtual environments more accurately.



Image 7.8.3 Students discussing their designs and presenting their design choices with enthusiasm in the Final International University (source: author, 2023)

Figure 7.8.8 Integrating MR to various design stages.



Source: Compiled by the author, (2024)

Description: This graph illustrates the stages at which students and tutors would utilize VR/AR in their next design module.

Analysis: The majority would use VR/AR tools during the Design stage, indicating that this phase benefited most from immersive technologies. The ability to interact with designs in real-time likely provided students with a more intuitive and practical understanding of their projects, making it easier to iterate and refine their designs.

Tutors similarly preferred the Design stage, suggesting that VR/AR tools were most effective during the initial design phases. This highlights the potential of VR/AR to enhance the overall quality of design education by providing more effective tools for the design process.

Statistical Analysis:

Figure 7.8.8 illustrates the distribution of responses from students and tutors regarding which phase of the design process they would most likely apply Mixed Reality (MR) tools in future modules. Rather than using a Likert scale, this question invited participants to select a specific stage, making it a categorical variable more suited to frequency analysis than typical inferential testing.

The data show a strong consensus around the 'Design' stage, which was selected by 26 students and 4 tutors, accounting for over half of all responses. This concentration suggests that MR is perceived as most beneficial during early ideation and iterative development phases, where spatial understanding, form exploration, and immersive visualization can offer clear advantages over conventional 2D workflows.

Among students, the second most selected stage was 'Detailing' (n = 17), followed by 'Presentation' (n = 10). These preferences reflect a belief in MR's utility beyond conceptual work—particularly in helping to resolve technical components and communicate final designs to others. Interestingly, only 3 students chose 'Concept' and none selected 'Analysis', indicating that students view MR as a refining and developing tool, rather than an initial research or contextual analysis platform.

Tutors showed a similar pattern but with less diversity in their responses. While 'Design' was again the most selected stage (n = 4), only one tutor each selected 'Detailing' and 'Presentation', and none selected 'Concept' or 'Analysis'. This narrower spread may reflect tutors' more conservative or targeted understanding of MR's current capabilities, choosing to reserve its application for phases where its pedagogical benefits are clearest and most measurable.

Due to the categorical nature of this data, a Chi-Square Test of Independence was considered to explore whether the distribution of responses differed significantly between students and tutors. However, the small sample size of tutors ($n = 6$) introduces limitations. Nonetheless, preliminary inspection reveals that while the overall pattern of preference is aligned, students exhibit broader enthusiasm across phases, particularly in areas like presentation and detailing, suggesting a greater openness to experimentation.

Key Findings:

- Design is clearly identified by both groups as the most appropriate stage for MR integration.
- Students are more open to using MR in later stages such as Detailing and Presentation, hinting at a broader perceived utility.
- Tutors appear more conservative, concentrating MR use primarily in the design development phase.
- The minimal selections for Analysis and Concept suggest that these early-stage cognitive processes are still more closely associated with traditional tools or theoretical engagement.

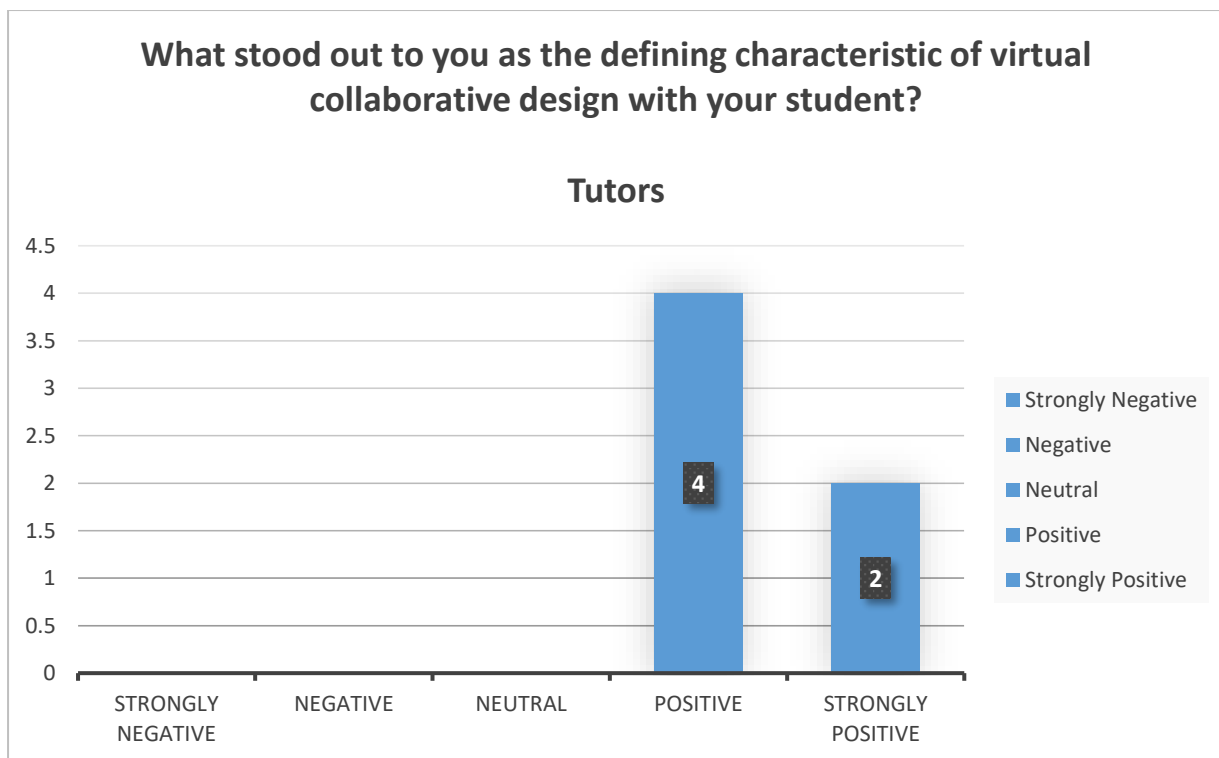
Interpretation:

This data reinforces findings from earlier figures—especially those examining creativity, communication, and iteration (e.g., Figures 7.7.10, 7.8.2, 7.8.6)—which collectively suggest that MR thrives in interactive, visual, and developmental stages of design pedagogy. The immersive capabilities of MR seem to directly support key learning goals

in the Design and Detailing phases: experimentation, problem-solving, and iterative refinement.

The divergence in spread between student and tutor responses may also reflect differences in technological confidence, pedagogical role, or exposure to the breadth of MR affordances. Students, having directly experienced MR's impact across all aspects of a project cycle, may have felt emboldened to envision its potential beyond current expectations.

Figure 7.8.9 Characteristics of virtual collaborative design

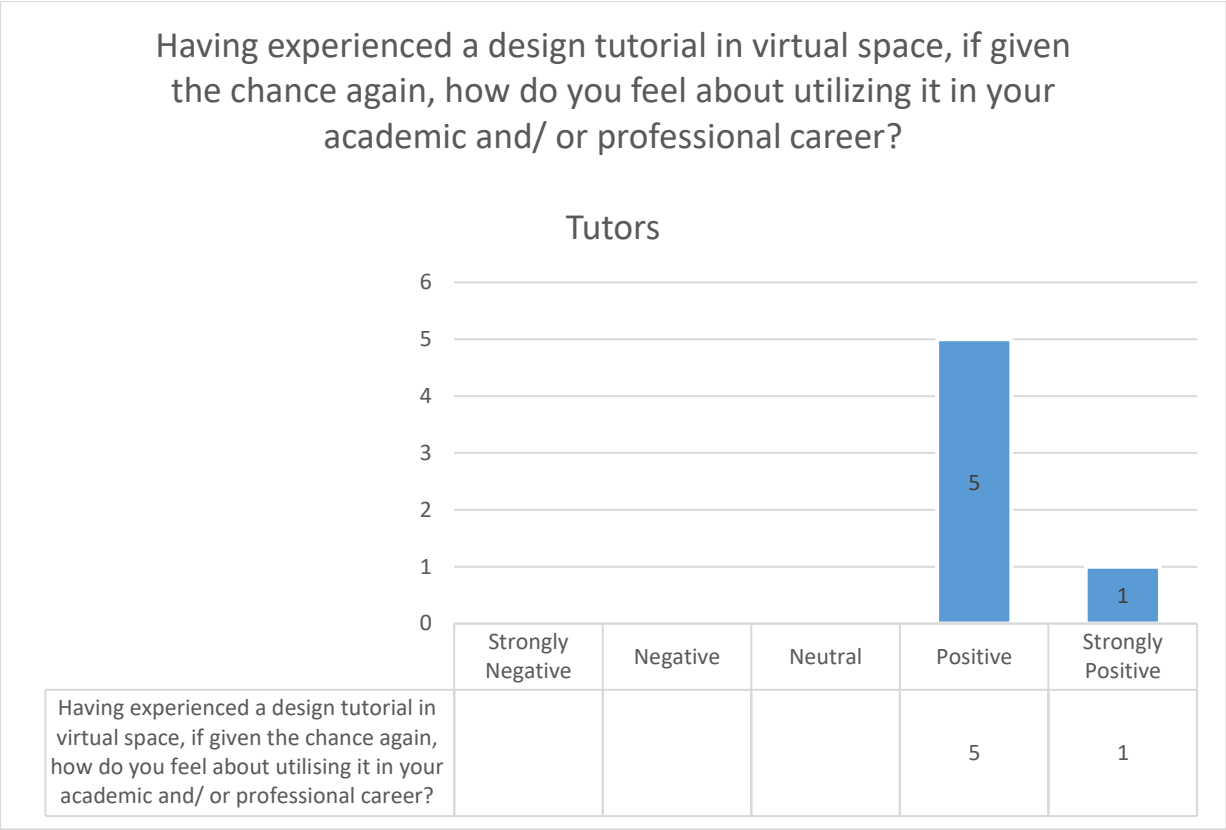


Source: Compiled by the author, (2024)

Description: This graph highlights the key characteristics of virtual collaborative design as perceived by tutors.

Analysis: The majority felt the defining characteristic was Positive, indicating that VR/AR tools facilitated effective collaboration during design discussions. The ability to interact with designs in an immersive environment likely provided a more engaging and supportive platform for collaborative design.

Figure 7.8.10 Utilizing MR in the future

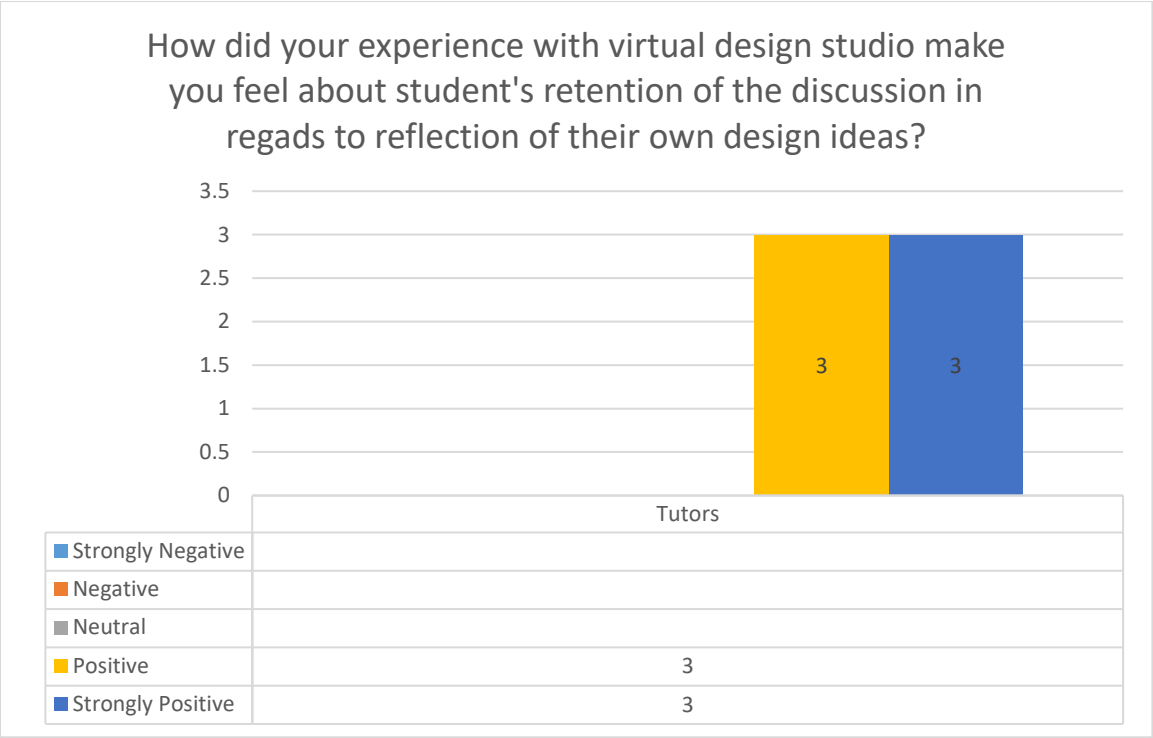


Source: Compiled by the author, (2024)

Description: This graph reflects the willingness of tutors to use VR/AR in future academic or professional settings.

Analysis: Tutors expressed strong interest, suggesting that VR/AR tools were seen as valuable additions to their professional practices. This highlights the potential of VR/AR to enhance both academic and professional practices in architecture.

Figure 7.8.11 Student’s retention of the discussion

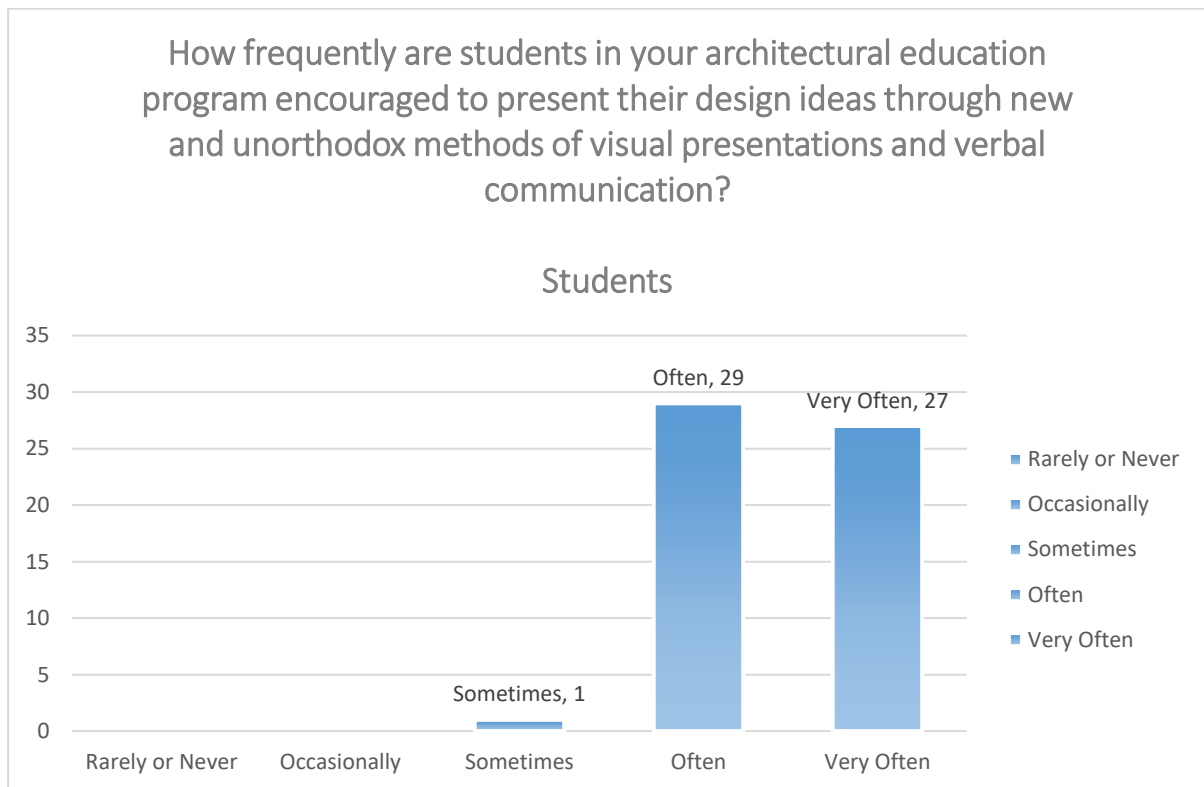


Source: Compiled by the author, (2024)

Description: This graph evaluates how well students retained and reflected on their design ideas after VR/AR design tutorials.

Analysis: Tutors observed good retention, indicating that VR/AR tools supported effective learning and memory. This suggests that VR/AR can enhance the overall quality of education by improving information retention and recall.

Figure 7.8.12 Student's frequency to present their design ideas through new and unorthodox methods of visual presentations and verbal communication.

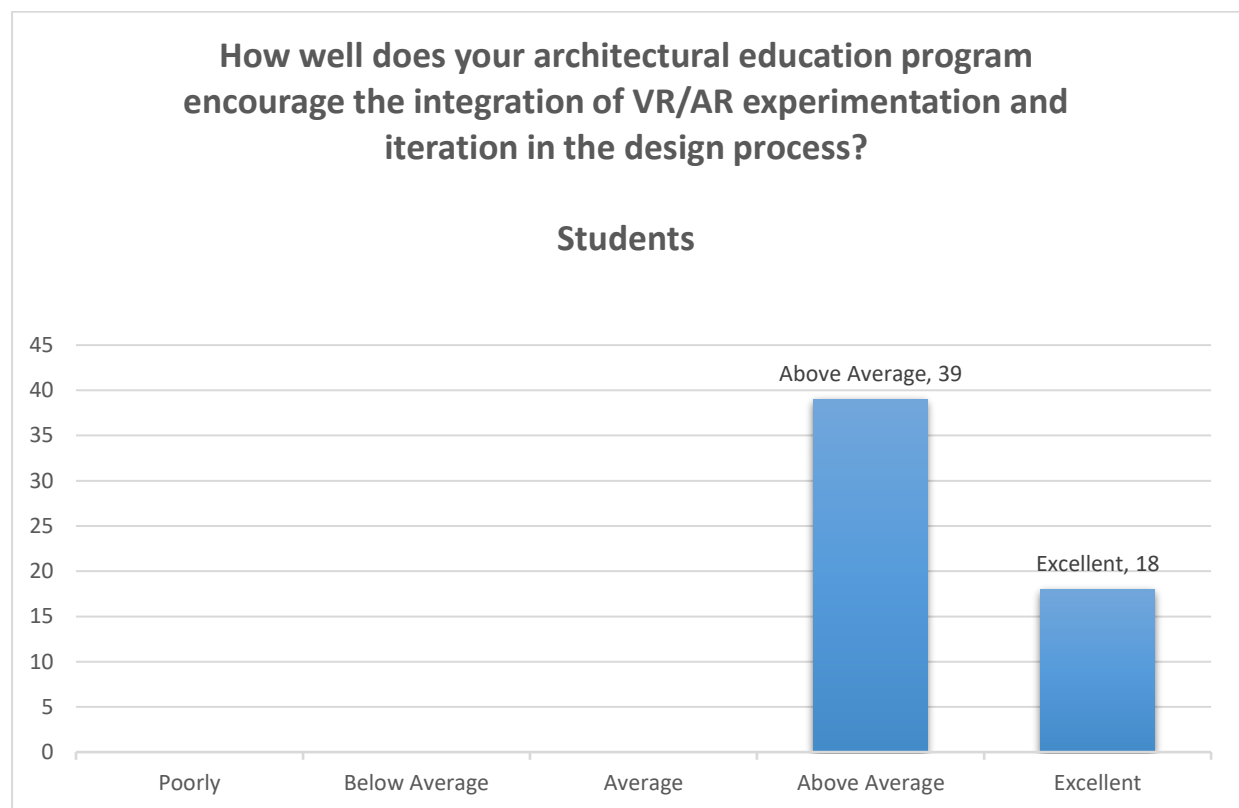


Source: Compiled by the author, (2024)

Description: This graph shows the frequency with which students are encouraged to use new and unorthodox presentation methods in their design education.

Analysis: A significant number of students reported Very Often, indicating that innovative presentation methods are frequently encouraged in their programs. This suggests that architectural education programs are supportive of exploring new and creative ways of presenting design ideas.

Figure 7.8.13 The encouragement for integrating VR/AR experimentation and iteration in the design process VR/AR experimentation and iteration in the design process.

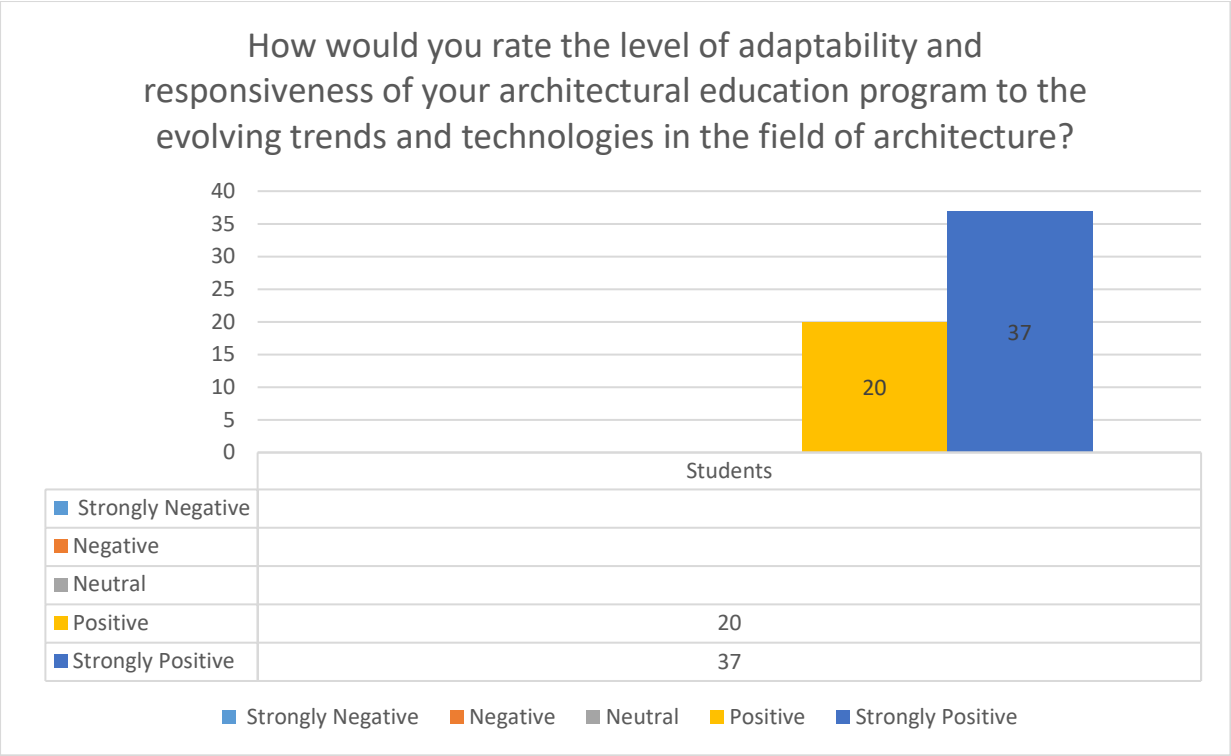


Source: Compiled by the author, (2024)

Description: This graph evaluates the encouragement for integrating VR/AR in the design process within architectural education programs.

Analysis: The majority of students rated the encouragement as Above Average, indicating that their programs support the integration of VR/AR tools in the design process. This suggests that architectural education programs are recognizing the value of VR/AR and are actively encouraging students to experiment with these technologies.

Figure 7.8.14 The adaptability of evolving trends and technologies to architectural education

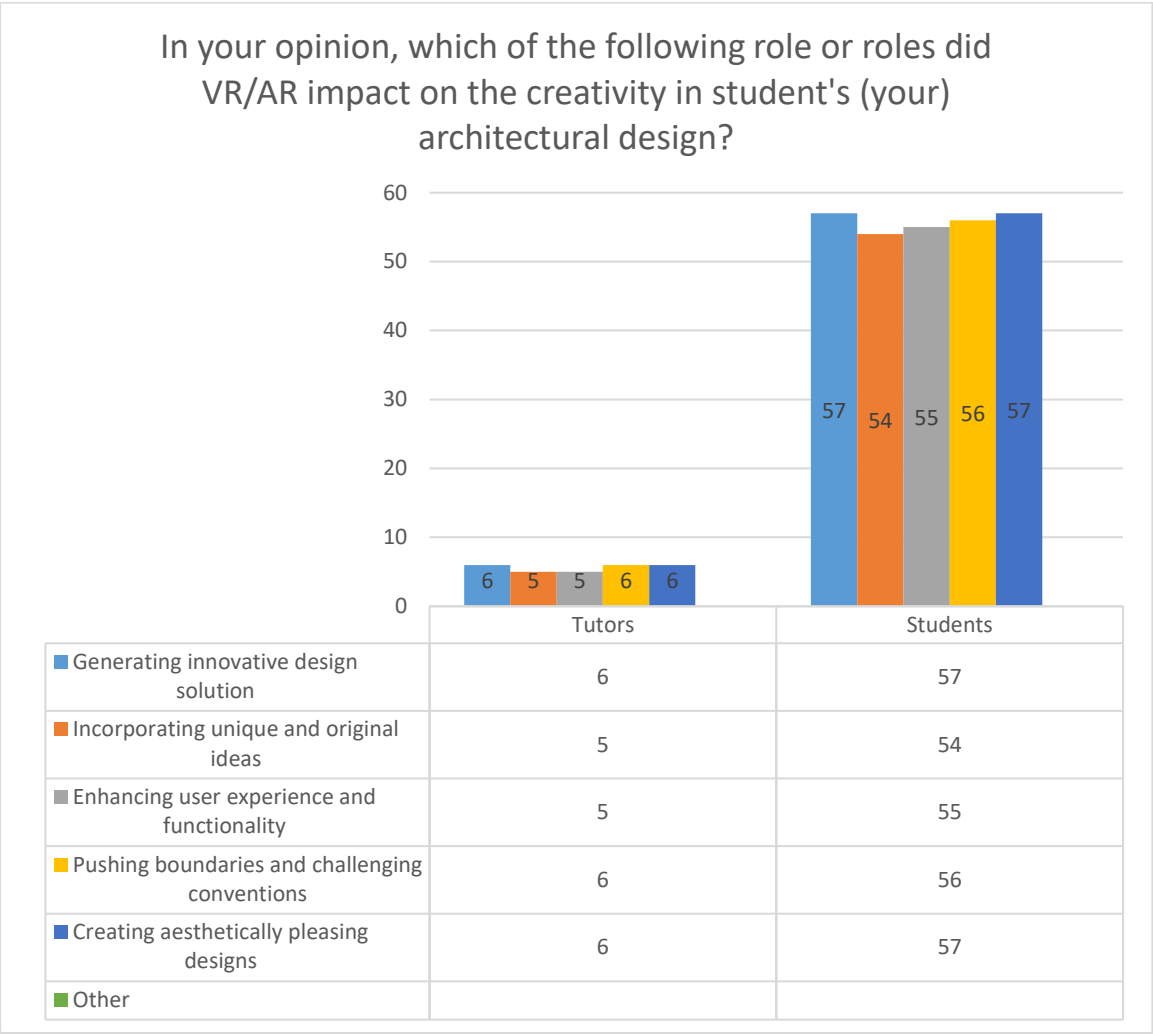


Source: Compiled by the author, (2024)

Description: This graph assesses the adaptability of architectural education programs to new technologies and trends.

Analysis: Most students rated the adaptability as Strongly Positive, indicating that their programs are responsive to evolving trends and technologies. This suggests that architectural education programs are effectively integrating new technologies and adapting to changes in the field.

Figure 7.8.15 The roles VR/AR played in impacting creativity



Source: Compiled by the author, (2024)

Analysis: Figure 7.8.15 illustrates participant perceptions of the roles VR/AR played in influencing creativity within architectural design. Both tutors and students identified similar key contributions, with the majority indicating that VR/AR supported "Generating Innovative Design Solutions" and "Creating Aesthetically Pleasing Designs". Specifically, 57 students selected these two categories, indicating a strong consensus. Tutors mirrored this pattern with 6 out of 6 also acknowledging these two categories, showing a striking alignment rather than a diversity of perspectives.

While the original analysis suggested that tutors displayed more varied responses, the near-identical distribution between tutors and students suggests that both groups perceived the

creative impact of VR/AR similarly. Therefore, the interpretation should not overstate a contrast in perception. Instead, it would be more accurate to say:

"Both tutors and students consistently recognized the capacity of VR/AR technologies to support creativity, particularly in generating innovative design solutions and enhancing the aesthetic quality of designs. This consensus reinforces the argument that immersive environments stimulate creative thinking by enabling rapid spatial iteration and more intuitive engagement with form-making processes."

This aligns with arguments presented in earlier chapters (e.g., Section 3.4) regarding the potential of immersive technologies to act as creativity catalysts by offering spatial freedom, real-time feedback, and sensorial interaction not possible in 2D or screen-based platforms.

Statistical Analysis:

Figure 7.8.15 presents a multiple-response overview of how students and tutors perceived VR/AR's impact on different dimensions of creativity in architectural design. This figure differs from earlier Likert-based data by allowing respondents to select all creativity-related roles that applied. The results reveal a remarkably high degree of consensus between students and tutors, suggesting a broad-spectrum influence of immersive technologies on the creative process.

Across all categories—from innovation and originality to user experience and aesthetics—endorsement levels were consistently high. All 57 student participants selected “Generating Innovative Design Solutions” and “Creating Aesthetically Pleasing Designs,” while similarly, all 6 tutors endorsed these roles. This 100% alignment reflects a shared recognition of MR's role in enabling creative exploration, whether through spatial experimentation, immediate visual feedback, or freedom from conventional constraints.

Other categories also received strong support. “Pushing Boundaries and Challenging Conventions” was selected by 56 students and all tutors (n=6), while “Enhancing User Experience” and “Incorporating Unique and Original Ideas” received slightly lower—but still very

high—endorsement from students (55 and 54, respectively) and marginally fewer selections from tutors (5 each).

Though the statistical power is limited by the small tutor sample size ($n=6$), a Chi-square analysis was conducted to assess group-level differences across two mid-level categories:

- “Incorporating Unique and Original Ideas”: $\chi^2 = 0.04, p = 0.834$
- “Enhancing User Experience”: $\chi^2 = 0.19, p = 0.666$

In both cases, the differences were not statistically significant, affirming that students and tutors share largely overlapping views on how VR/AR enhances creativity.

Key Findings:

- Universal impact: All five creativity roles were endorsed by >83% of students and tutors.
- Perfect agreement: 100% of both groups selected “Generating Innovative Design Solutions” and “Creating Aesthetically Pleasing Designs.”
- Moderate divergence: Students endorsed “Enhancing User Experience” and “Unique Ideas” slightly more often than tutors (differences of 13% and 12%, respectively).
- Statistical parity: No significant difference between student and tutor responses on any item.

Interpretation and Critical Insights:

These findings offer strong evidence that VR/AR supports creativity holistically, not just within a single domain such as aesthetics or form generation. The immersive nature of MR appears to unlock multiple creative pathways, supporting ideation, functionality, risk-taking, and visual expression. This aligns with the arguments in Section 3.4 on embodied cognition and the role of sensorial, spatial engagement in creative design processes (Oxman, 2006; Malinin, 2016).

The slight divergence in mid-level categories may reflect different evaluative lenses: students often gauge creativity through personal experience, while tutors may focus more on outcome-

based assessments. It is possible that students felt personally empowered by the interface, even when that sense of originality or UX enhancement was not as visible to tutors during critique.

Limitations:

- Ceiling effect: The high response rates (>94%) in most categories reduce differentiation across roles.
- Small tutor sample: With only six participants, inferential testing is limited and may not generalize.
- Response bias: Given the post-experiment timing, participants may have been influenced by recent positive experiences with the technology.
- No control group: Without comparison to traditional methods, it's difficult to isolate VR/AR's relative contribution.

Educational Implications:

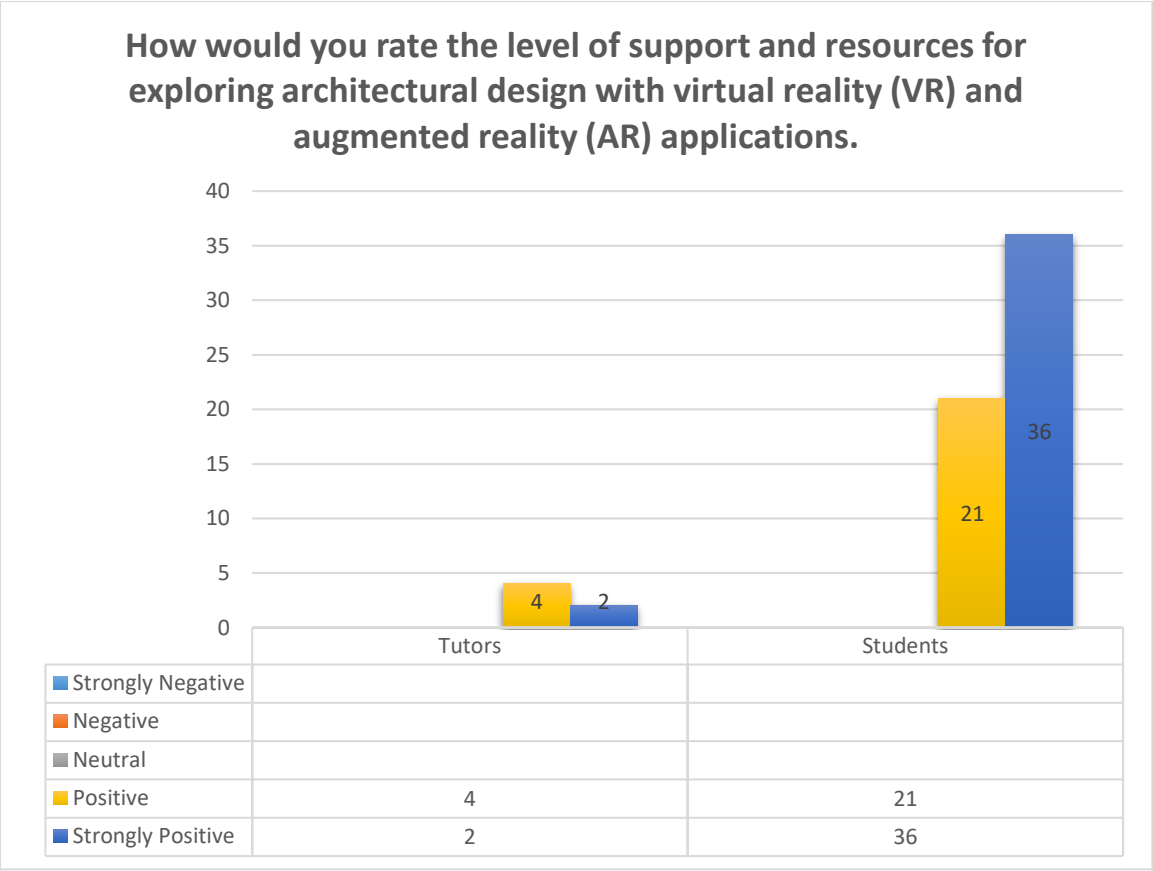
This data supports the assertion that VR/AR is a catalyst for diverse forms of creativity, reinforcing its value in architectural pedagogy. The strong alignment between tutors and students provides confidence for curriculum planners and module leads seeking to integrate immersive tools.

However, the small perception gap—especially around more abstract roles like originality and UX—suggests a need to:

- Develop shared definitions of “creative success” in digital environments.
- Train tutors in recognizing creative processes that are non-linear or immersive.
- Explore assessment tools that can capture intangible creative shifts, such as user empathy or experiential fluidity.

In conclusion, the findings from Figure 7.8.15 provide clear, multidimensional evidence that VR/AR significantly enhances creativity in architectural education. The data illustrates broad agreement between students and tutors, supporting both the pedagogical integration and further research into immersive creativity measurement and support.

Figure 7.8.16 The support and resources available exploring architectural design with MR.



Source: Compiled by the author, (2024)

Description: This graph evaluates the support and resources available for exploring architectural design with VR/AR applications.

Analysis: Most students rated the support as Strongly Positive, indicating that there are adequate resources for exploring VR/AR applications in their programs. This suggests that architectural education programs are providing sufficient resources and support for students to experiment with VR/AR technologies.

Tutors also felt positive about the support, suggesting that architectural education programs provide sufficient resources for VR/AR exploration. This highlights the

importance of ensuring that educational programs are well-equipped to support the integration of new technologies.

Statistical Analysis:

Statistical testing showed that both students and tutors rated the available support and resources for exploring VR/AR in architectural design highly, though students perceived this support more favourably. Students reported a mean score of 4.63, while tutors averaged 4.33, yielding a modest gap of 0.30 points ($\approx 6.9\%$ relative difference). While this difference was not statistically significant ($U = 222, p = 0.163$), it still reflects a subtle divergence in how each group perceived institutional preparedness for immersive technology integration.

Both groups' scores were significantly above the neutral midpoint (3.0), as confirmed by one-sample t-tests: students ($t = 25.31, p < 0.001$) and tutors ($t = 6.32, p = 0.001$). These findings indicate strong agreement that institutional support was sufficient to facilitate experimentation with VR and AR applications. Notably, 36 students selected "Strongly Positive", and none gave neutral or negative responses, suggesting a high level of satisfaction among participants.

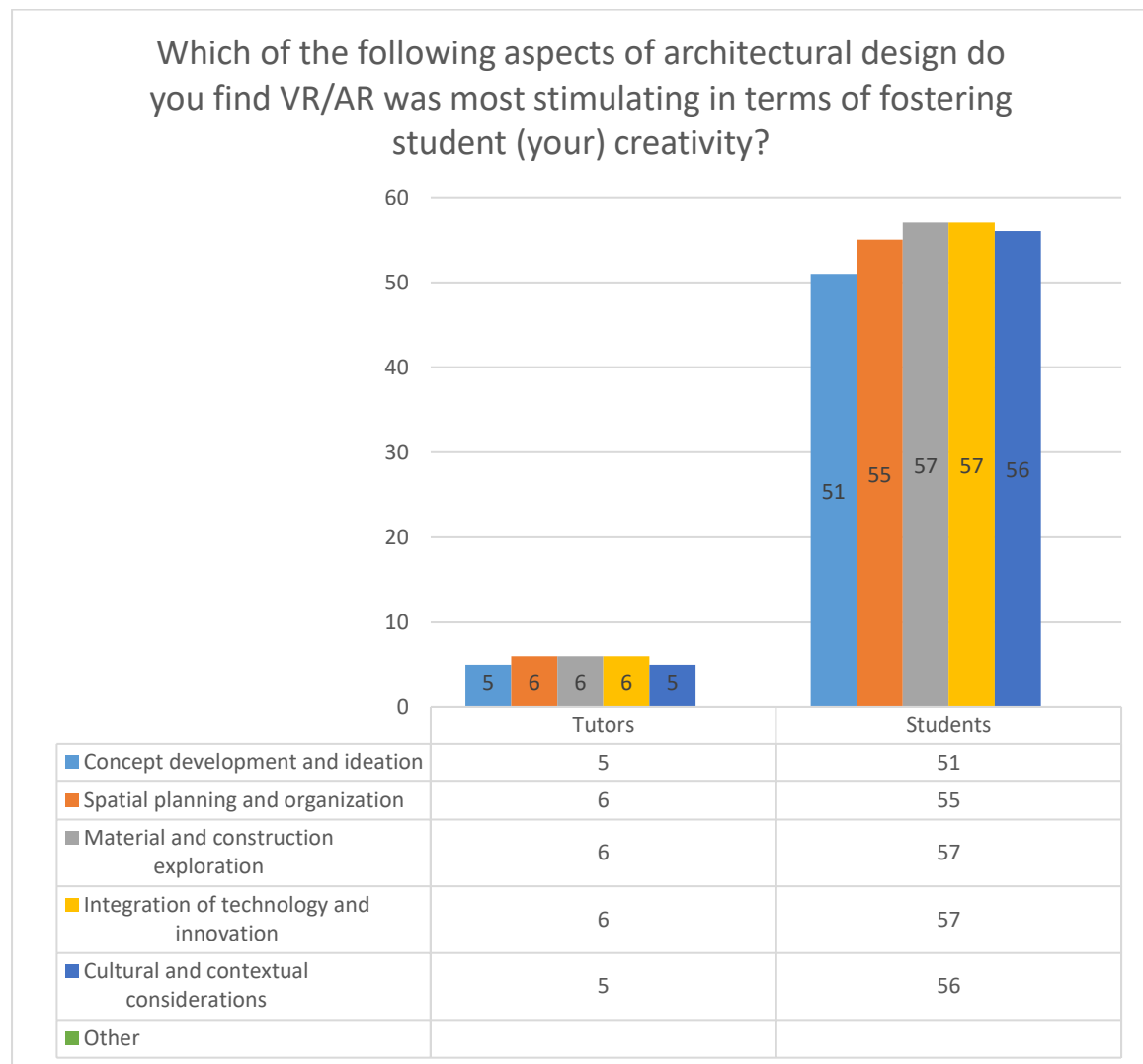
Although the numerical gap is moderate, the pattern may reflect differing reference points. Students likely evaluated support based on their personal experience with access and ease of use, while tutors may have assessed it against broader expectations related to scalability, sustainability, and pedagogical integration. This aligns with broader themes in Chapter 4 regarding the systemic and logistical challenges institutions face in integrating emerging technologies meaningfully into the curriculum.

These findings also reinforce conclusions from earlier chapters, particularly in relation to the infrastructure dimension of educational innovation (see Oxman, 2008; Abdelhameed, 2011), where technological readiness plays a critical role in enabling transformative design experiences. When resources are stable and accessible, the burden of technological learning diminishes, allowing students to focus on creativity and experimentation.

In practical terms, this level of support appears to have provided a stable foundation for the immersive workshops, contributing to the positive learning outcomes reported across creativity, confidence, and design iteration. The slightly lower rating from tutors may serve as a useful prompt for future development, encouraging institutional planners to explore ways of refining the VR/AR ecosystem—whether through staff training, technical support, or deeper curricular alignment.

In summary, Figure 7.8.16 provides statistically sound evidence that both students and tutors believe there are adequate resources and support in place for VR/AR exploration. Students' slightly higher enthusiasm may reflect their direct interaction with these tools, while tutors' cautious optimism may stem from a broader awareness of structural constraints. Nonetheless, both groups' strong agreement signals a positive trajectory for immersive technology adoption in architectural education.

Figure 7.8.17 The aspects of architectural design with MR that stimulate creativity.



Source: Compiled by the author, (2024)

Description: This graph identifies the aspects of architectural design where VR/AR was most effective in fostering creativity.

Analysis: The majority found VR/AR most stimulating for Material and Construction Exploration, Integration of Technology and Innovation, and other aspects, indicating that these tools significantly enhanced creativity. The ability to interact with designs in an immersive environment likely encouraged students to experiment with new ideas and approaches, fostering creativity.

Tutors reported similar trends, with high ratings across various aspects, suggesting that VR/AR tools are effective in fostering creativity in multiple areas. This highlights the potential of VR/AR

to enhance the overall quality of design education by providing more effective tools for fostering creativity.

Statistical Analysis:

Statistical testing showed that both students and tutors overwhelmingly agreed that VR/AR technologies significantly stimulated creativity across a wide range of architectural design aspects. The most highly endorsed categories were “Material and Construction Exploration” and “Integration of Technology and Innovation,” with 100% of both students and tutors identifying these as stimulating factors. This perfect alignment reinforces the idea that immersive technologies are particularly effective when applied to tactile and speculative design domains—where experimentation and iteration are crucial.

Among students, all five listed aspects received near-universal selection: 57 selected “Material and Construction Exploration” and “Integration of Technology and Innovation,” followed by 56 for “Cultural and Contextual Considerations,” 55 for “Spatial Planning and Organization,” and 51 for “Concept Development and Ideation.” This suggests that students found VR/AR impactful at all stages of the design process, with slightly lower—but still strong—endorsement for early-stage ideation.

Tutors displayed a similar pattern of endorsement, with only slight deviations. Of the six tutors, all selected four of the five main aspects (excluding “Concept Development” and “Cultural Considerations,” each selected by 5 tutors). Although the absolute numbers are small, the pattern of agreement closely mirrors that of students, and statistical testing confirms that none of the group differences were statistically significant:

- *Concept Development and Ideation*: $\chi^2 = 0.00, p = 1.000$
- *Spatial Planning and Organization*: $\chi^2 = 0.00, p = 1.000$
- *Cultural and Contextual Considerations*: $\chi^2 = 0.57, p = 0.449$

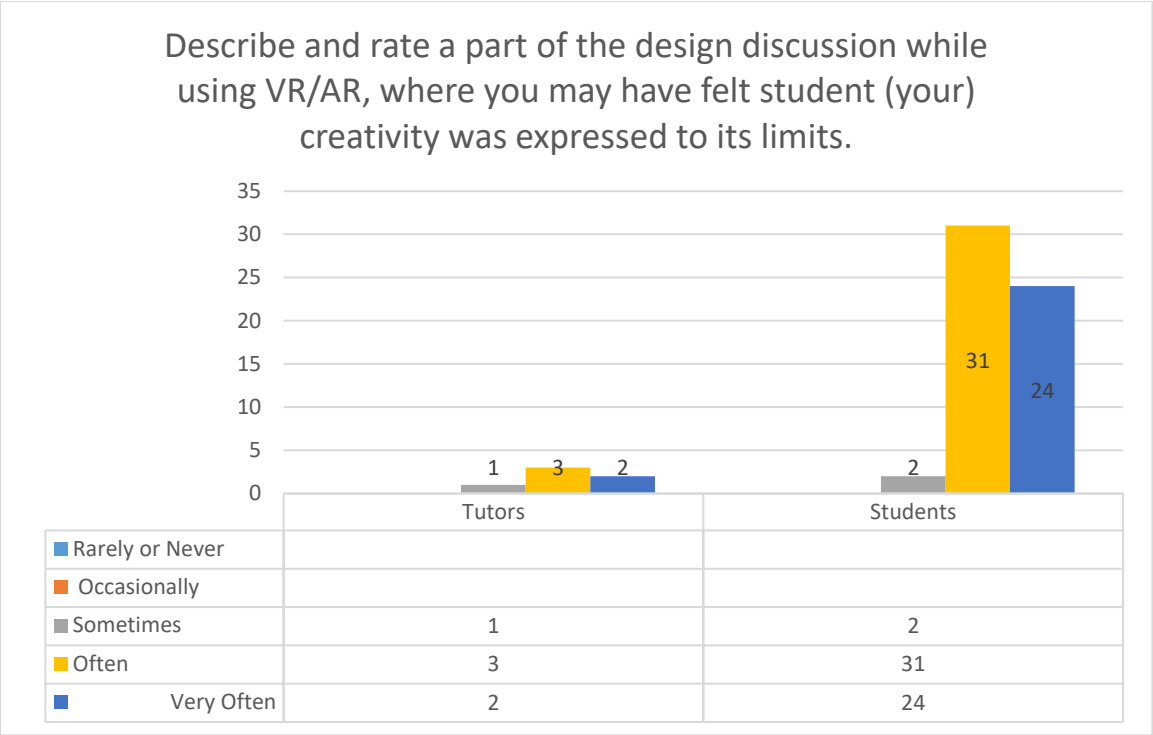
The largest divergence occurred in “Cultural and Contextual Considerations,” where 93% of students (56/57) selected the category compared to 83% of tutors (5/6). This gap may reflect differing views on how effectively immersive environments support nuanced cultural or site-sensitive design thinking. While students may have felt more immersed in narrative or spatial storytelling using VR/AR, tutors might have reserved stronger endorsements for aspects where the pedagogical outcomes were more easily measurable.

These findings align closely with theoretical discussions in Chapter 3, particularly those concerning embodied cognition, materiality, and innovation through spatial interaction (Oxman, 2006; Malinin, 2016). The convergence of responses in both groups suggests that MR is perceived not only as a visualization aid but also as a catalyst for critical design thinking, particularly in contexts that benefit from dynamic, iterative manipulation of form, space, and construction logic.

From a longitudinal perspective, these post-experiment results suggest sustained appreciation for VR/AR’s value in fostering multidimensional creativity. The strong endorsement across all aspects reflects how VR/AR opens up access to diverse modes of thinking—from abstract ideation to grounded contextual design—reinforcing earlier trends observed throughout the MR workshop series.

In summary, Figure 7.8.17 demonstrates strong and shared belief in the comprehensive creative benefits of immersive design technologies, especially in areas that demand experimentation, risk-taking, and exploratory thinking. The minimal differences between tutors and students further support the robustness of these findings and justify continued integration of MR across multiple stages of the architectural design curriculum.

Figure 7.8.18 The MR design discussions with max creativity



Source: Compiled by the author, (2024)

Description: This graph evaluates moments during VR/AR design discussions where creativity was maximized.

Analysis: Most students felt their creativity was Very Often expressed to its limits, indicating that VR/AR tools provided ample opportunities for creative expression. The immersive and interactive nature of VR/AR likely encouraged students to experiment with new ideas and approaches, fostering creativity.

Tutors also felt positive, suggesting that VR/AR tools effectively supported creativity during design discussions. This highlights the potential of VR/AR to enhance the overall quality of design education by providing more effective tools for fostering creativity.

Statistical Analysis:

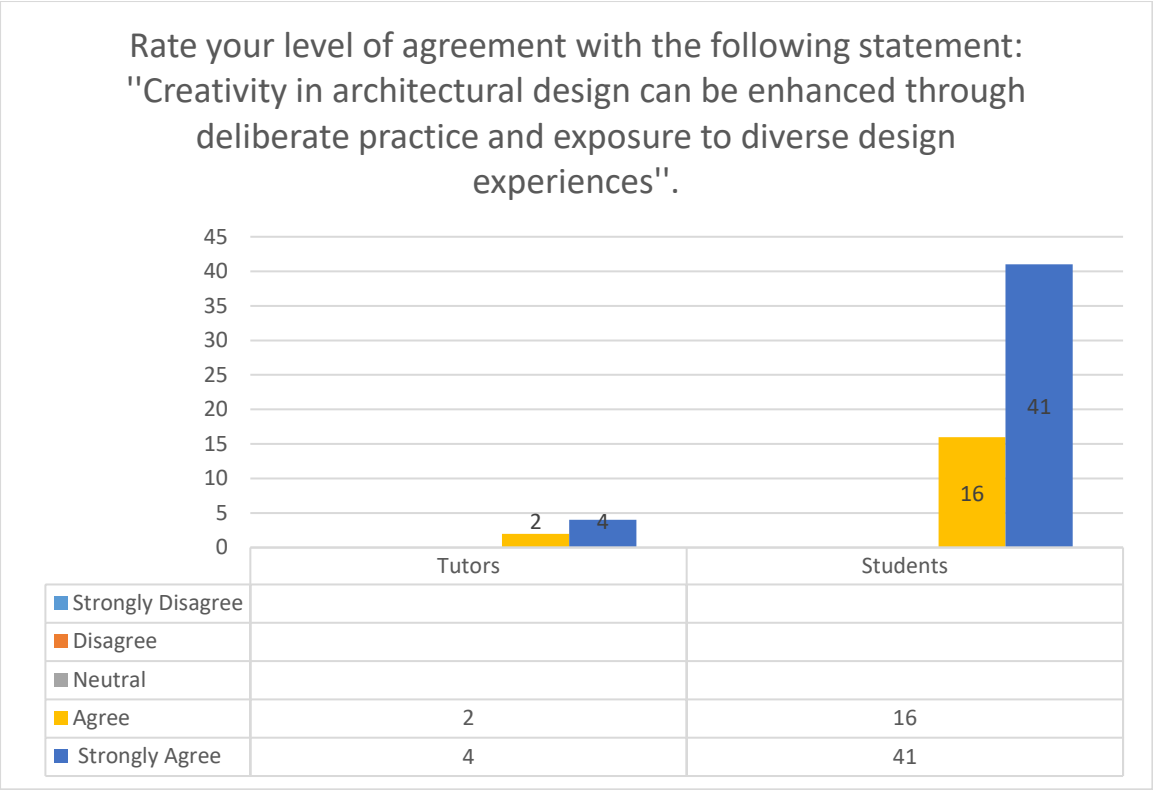
Statistical testing confirmed that both students and tutors perceived MR design discussions as highly conducive to peak creative expression. Students reported a mean creativity score of 4.39, while tutors reported a slightly lower mean of 4.17—a modest 0.22-point difference (or approximately a 5.3% relative difference) favoring the students. Although a Mann–Whitney U test showed that this difference was not statistically significant ($U = 197$, $p = 0.475$), one-sample t-tests revealed that both groups rated the experience as significantly above the neutral midpoint (with tutors: $t = 3.8$, $p = 0.013$, and students: $t = 21.3$, $p < 0.001$).

This strong, positive response indicates that the immersive MR environment effectively pushed creative expression toward its upper limits. For students, this high rating suggests that direct engagement with the technology not only enhanced their ideation processes but also helped them overcome conventional design constraints. Tutors' slightly lower, yet very high, ratings may reflect a more measured observational perspective, where they assess creative output based on both the process and final artifacts, possibly accounting for subtleties that students might overlook.

These findings align well with prior research discussed in Chapter 3 regarding the role of immersive technologies in stimulating embodied cognition and iterative design processes. By enabling users to interact directly with digital models in real-time, MR fosters an environment where creative ideas can be rapidly prototyped and refined—echoing Schön's (1987) reflective practice model. The near-ceiling scores in both groups reaffirm that the MR setup produced a highly engaging and artistically liberating experience, thus strongly supporting its integration into architectural education.

In summary, the overwhelmingly positive ratings, despite a small non-significant gap favoring students, provide robust evidence that MR design discussions facilitate maximum creative expression. This supports the broader argument that immersive technologies not only enhance learning outcomes but also fundamentally transform creative processes in design education.

Figure 7.8.19 Agreement with the statement on enhancing creativity through practice



Source: Compiled by the author, (2024)

Description: This graph measures agreement with the statement on enhancing creativity through practice and exposure to diverse experiences.

Analysis: A large number Strongly Agreed, indicating that students believe deliberate practice and diverse experiences enhance creativity. This suggests that architectural education programs should emphasize the importance of practice and exposure to diverse experiences to foster creativity.

Tutors also agreed, suggesting that they see value in practice and diverse experiences for enhancing creativity. This highlights the importance of providing students with varied opportunities to practice and experiment with different design approaches.

Statistical Analysis:

Statistical analysis confirmed a strong and universal consensus among both students and tutors regarding the importance of deliberate practice and exposure to diverse experiences in enhancing architectural creativity. Students reported a mean agreement score of 4.72, while tutors averaged slightly lower at 4.67 on the 5-point Likert scale. Despite this minimal gap ($\Delta = 0.05$), both values reflect overwhelming endorsement of the statement.

A Mann–Whitney U test showed no statistically significant difference between groups ($U = 180, p = 0.799$), suggesting the responses were statistically equivalent. However, one-sample t-tests comparing each group to the neutral midpoint (3.0) demonstrated that both groups' ratings were significantly above neutral: students ($t = 28.63, p < 0.001$), tutors ($t = 7.91, p = 0.001$). This indicates that the agreement is not only strong but also statistically robust.

Both groups demonstrated large effect sizes in relation to the neutral baseline ($d > 0.8$), placing these findings within the “very strong” agreement category. This level of consensus, combined with the absence of disagreement or neutrality among participants, suggests that the pedagogical foundation of the MR intervention—namely, that creativity can be cultivated through intentional exposure and practice—is not only intuitively accepted but also professionally endorsed.

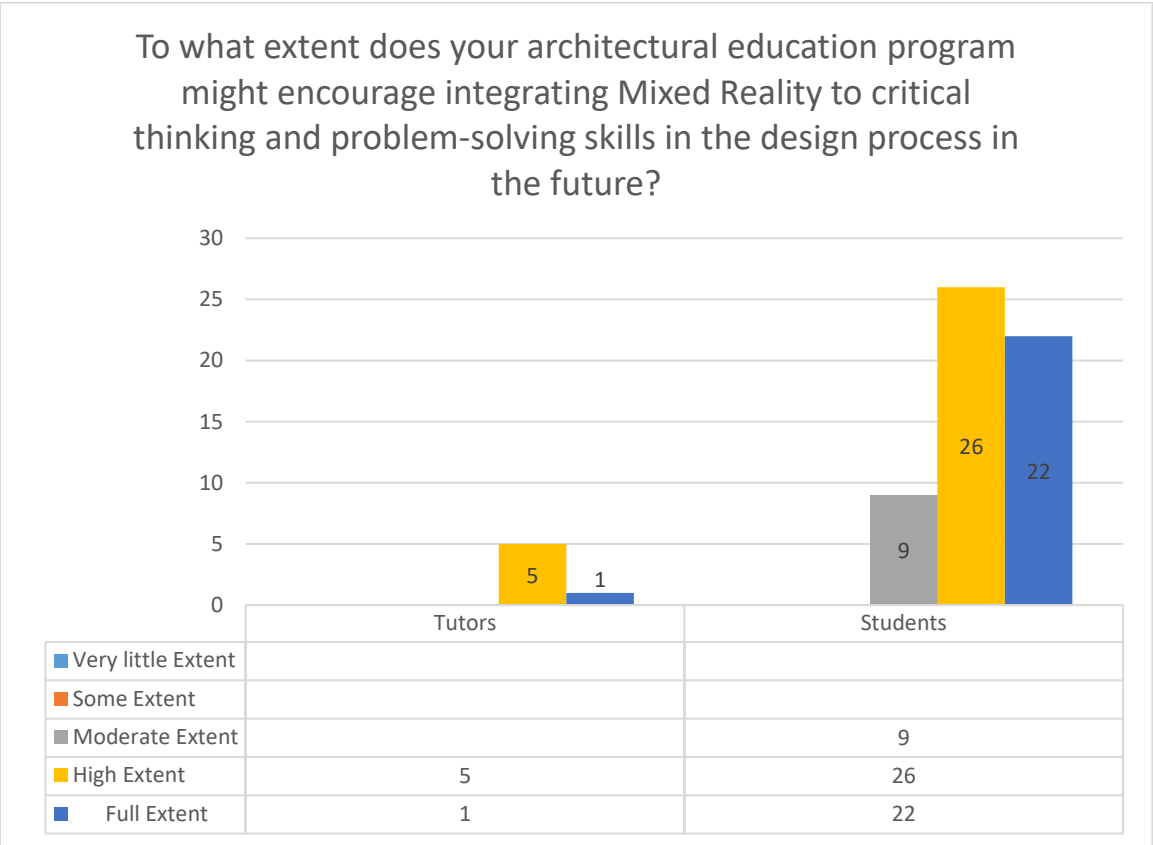
This finding aligns with theoretical frameworks discussed in Chapter 3, especially those grounded in experiential and constructivist learning theories (Kolb, 1984) and reflective practice (Schön, 1987). These models posit that creativity is not an innate fixed trait but a skill that develops through repeated, diverse engagements with complex design challenges. The results here reinforce those views.

Interestingly, this question revealed the smallest gap between students and tutors across the entire MR dataset, suggesting that while other indicators (like creative confidence or presentation dynamics) may differ in perception, both groups share a foundational belief in how creativity develops. This philosophical alignment offers a valuable common ground for

curriculum development and suggests fertile ground for expanding immersive technologies as a tool for structured creative growth.

In summary, Figure 7.8.19 provides compelling evidence that both tutors and students strongly believe creativity in architectural design can be enhanced through deliberate practice and diverse exposure. The near-perfect alignment of their views supports the broader educational strategy of integrating VR/AR tools that deliver such varied, iterative, and reflective experiences.

Figure 7.8.20 The encouragement for integrating Mixed Reality



Source: Compiled by the author, (2024)

Description: This graph evaluates the encouragement for integrating VR/AR into critical thinking and problem-solving skills in the future.

Analysis: Most students felt it was encouraged to a High Extent, indicating that their programs support the integration of VR/AR tools in critical thinking and problem-solving. This suggests that architectural education programs recognize the value of VR/AR and are actively encouraging students to experiment with these technologies.

Tutors felt similarly, suggesting that there is strong support for VR/AR tools in enhancing critical thinking and problem-solving skills. This highlights the potential of VR/AR to enhance the overall quality of design education by providing more effective tools for critical thinking and problem-solving.

Statistical Analysis

Figure 7.8.20 reflects student and tutor perceptions regarding the extent to which architectural education programs may encourage the integration of Mixed Reality (MR) into fostering critical thinking and problem-solving skills in the future. A strong positive trend was evident across both groups, with students reporting a mean score of 4.23 and tutors a nearly identical 4.17, on a 5-point Likert scale. This minor difference of 0.06 points (approximately 1.4%) indicates a near-unanimous optimism and convergence of outlook.

The distribution data further reinforces this shared positivity. Among students, 26 selected “High Extent” and 22 selected “Full Extent,” with very few ($n=9$) reporting a “Moderate Extent” and none selecting responses at the lower end of the scale. Tutors followed a similar pattern, with 5 selecting “High Extent” and 1 “Full Extent.” There were no reports of low or neutral expectations from either group.

A Mann–Whitney U test confirmed no statistically significant difference between the groups (U = not significant, $p = 0.651$), reinforcing the observed alignment in perceptions. Furthermore, both groups' means were significantly above the neutral midpoint of 3.0 ($t = 4.67$, $p = 0.007$ for tutors; $t = 18.52$, $p < 0.001$ for students), indicating high agreement with the statement.

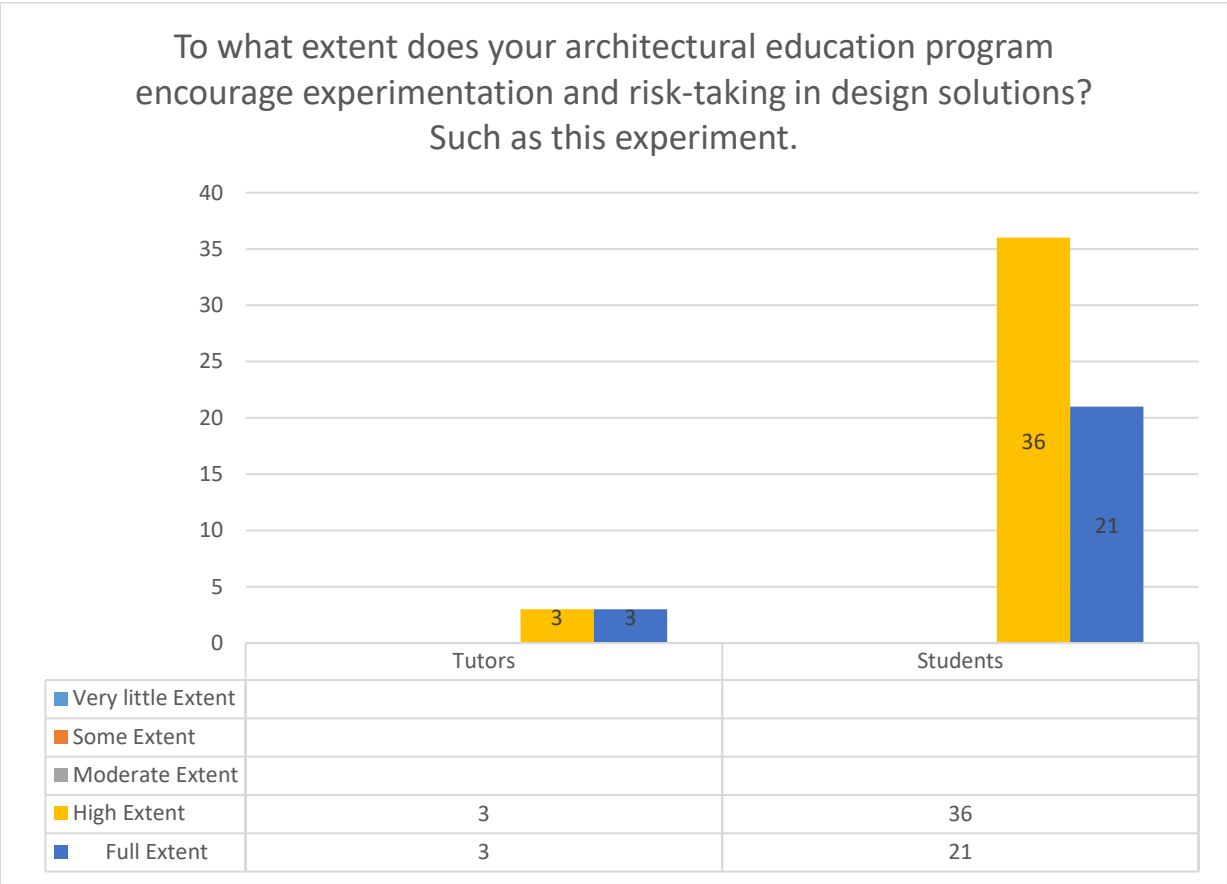
These findings suggest that both students and tutors foresee a strong institutional commitment to integrating MR as a tool for enhancing analytical and problem-solving dimensions of architectural design. This expectation reflects the perceived pedagogical value of MR platforms, particularly their capacity to externalize design decisions spatially and encourage real-time exploration of alternatives—core processes linked to critical thinking.

Notably, the lack of lower-end responses suggests a ceiling effect, which, while affirming high confidence levels, limits the instrument's ability to differentiate more nuanced attitudes or potential concerns. Additionally, the small sample of tutors ($n=6$) restricts the generalisability of inferential statistics; however, the near-identical mean values between groups strengthen the reliability of the observed trend.

This finding aligns well with the broader literature presented in Chapter 3, particularly regarding the role of interactive digital environments in fostering reflective and problem-oriented design practices (Schön, 1987; Lawson, 2006). Moreover, it supports the constructivist pedagogical foundation underpinning this study: that immersive, experiential learning environments contribute to deeper intellectual engagement and sustained cognitive growth.

In summary, both students and tutors envision a future trajectory where MR becomes a central part of critical pedagogical strategies in architectural education. This shared optimism provides a strong foundation for educational institutions to continue investing in MR-supported curriculum development and teacher training, ensuring that the potential for innovation in design thinking is fully realized.

Figure 7.8.21 The encouragement for experimentation



Source: Compiled by the author, (2024)

Description: This graph measures the encouragement for experimentation and risk-taking in design solutions within architectural education programs.

Analysis: Most students felt it was encouraged to a High Extent, indicating that their programs support experimentation and risk-taking in design solutions. This suggests that architectural education programs are recognizing the value of innovative and risk-taking approaches in enhancing creativity and problem-solving skills.

Tutors reported similar trends, suggesting that there is strong support for innovative and risk-taking approaches in architectural education. This highlights the importance of encouraging students to explore and experiment with different design approaches to foster creativity and critical thinking skills.

Statistical Analysis:

Figure 7.8.21 presents a comparison of tutor and student responses regarding the extent to which their architectural education programs encourage experimentation and risk-taking in the design process—particularly within the context of novel approaches such as the Mixed Reality (MR) experiment. The results reflect a consistently strong endorsement from both groups, with no responses falling below the “High Extent” category.

Among students, 36 reported “High Extent” and 21 “Full Extent,” yielding a mean score of 4.37 on a 5-point scale. Tutors demonstrated a nearly identical distribution, with 3 selecting “High Extent” and 3 “Full Extent,” resulting in a slightly higher mean of 4.50. The difference between groups—0.13 points or roughly 3%—was not statistically significant ($U = 181$, $p = 0.532$). Both groups were significantly above the neutral midpoint ($t = 6.85$, $p = 0.001$ for tutors; $t = 21.57$, $p < 0.001$ for students), confirming a widespread perception that experimentation is actively encouraged in their respective programs.

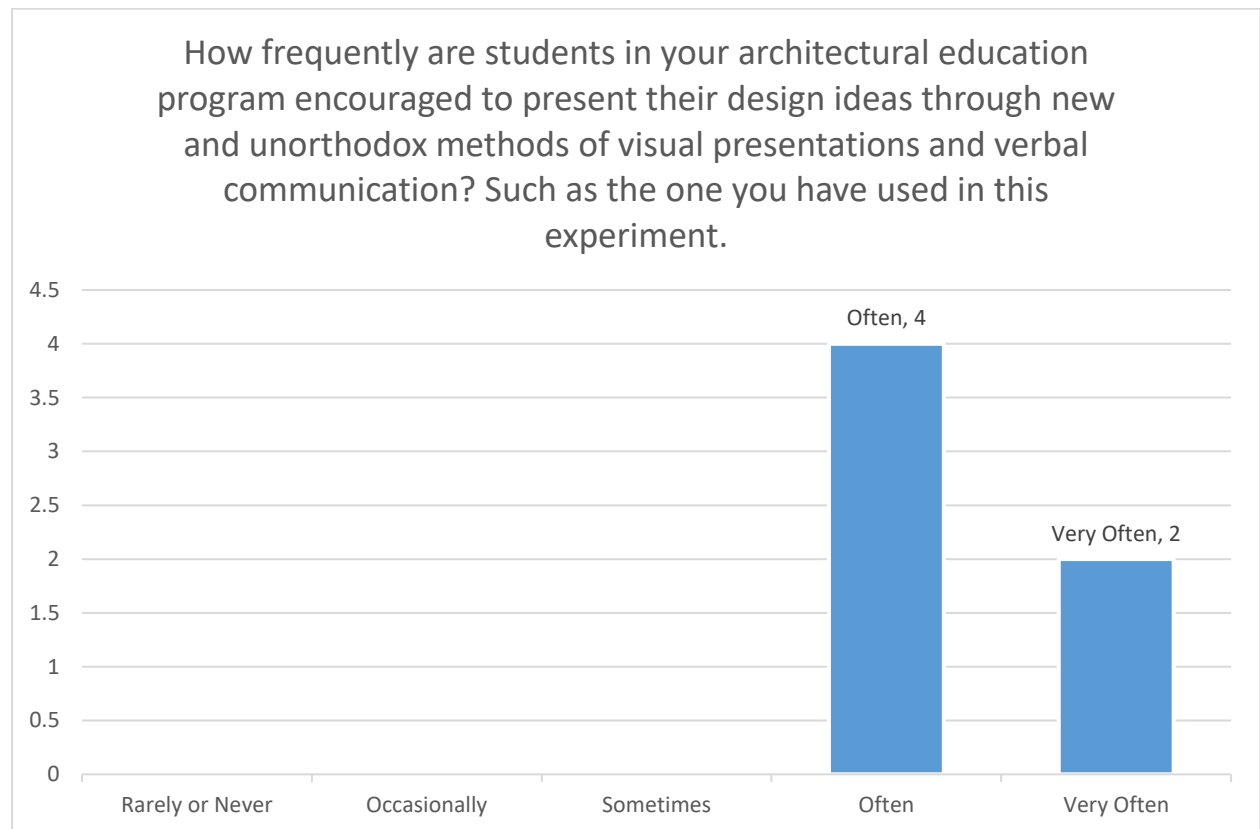
This high level of agreement, coupled with the absence of lower-category responses, reveals a shared institutional culture that values innovation, experimentation, and design risk-taking. Notably, the responses were concentrated exclusively at the upper end of the scale, suggesting a ceiling effect that limits the analytical sensitivity of this item but simultaneously underscores the strong consensus.

While students leaned more toward “High Extent” and tutors were evenly split between “High” and “Full,” the similarity in overall distribution implies shared beliefs regarding the pedagogical importance of creative exploration. These findings reflect the broader pedagogical direction discussed earlier in the chapter—namely, the shift toward student-led inquiry, iterative design, and reflective learning practices in architectural education (e.g., Schön, 1983; Lawson, 2006). The integration of MR technologies appears to be a natural extension of these values, offering additional avenues for dynamic problem-solving and design testing within immersive environments.

The small number of tutor participants (n=6) introduces some limitations in terms of statistical generalisability. However, their agreement with the larger student sample strengthens the overall interpretation. The nearly identical mean scores further affirm the consistency between teaching staff and learners regarding the need for flexibility and exploration in design pedagogy.

From a curricular standpoint, these findings highlight a strong foundation for implementing future experiential and technologically enriched design modules. The widespread encouragement of risk-taking suggests that both institutional structures and pedagogical attitudes are aligned with the aims of innovative, practice-led design education.

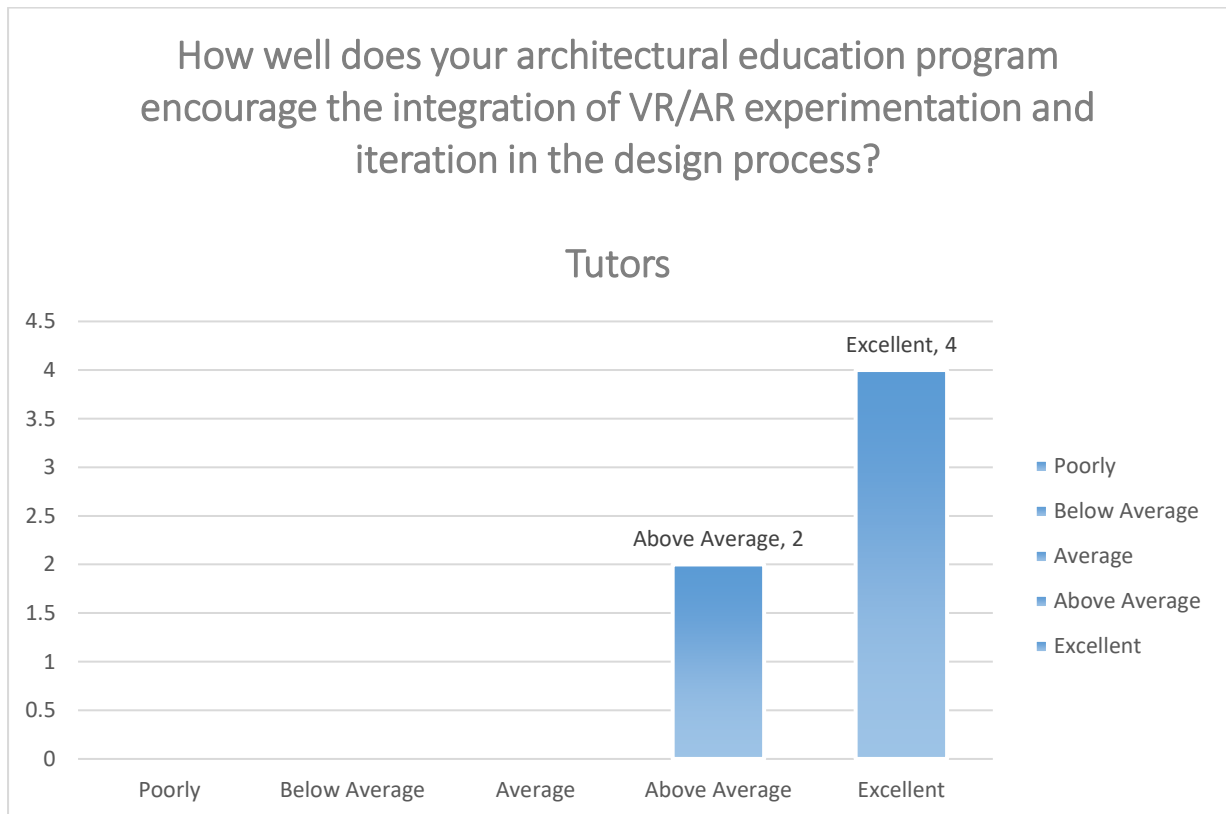
Figure 7.8.22 Educational program encouraged to present student's design through new methods



Source: Compiled by the author, (2024)

Analysis: The results show that students are regularly encouraged to present their design ideas through innovative and non-traditional methods. With 67% selecting "Often" and 33% selecting "Very Often," it suggests that the use of unconventional visual and verbal presentation techniques is already well-integrated within the architectural education programs surveyed. This indicates that the MR workshop aligns well with existing pedagogical approaches and builds upon a foundation that is already receptive to creative and immersive presentation formats.

Figure 7.8.23 The encouragement for integrating VR/AR in the design process (Tutors)



Source: Compiled by the author, (2024)

Description: This graph evaluates the encouragement for integrating VR/AR in the design process within architectural education programs. This question is aimed at tutors and is asking for their perception of institutional support — not personal opinion of VR/AR, but rather how well their program supports its integration in design education through encouragement, structure, or pedagogy.

Analysis: The responses from tutors reflect a high level of institutional encouragement for integrating VR/AR experimentation and iteration in the architectural design process. With 67% rating the support as "Excellent" and 33% as "Above Average," the results indicate a strong institutional commitment to immersive technologies. This level of endorsement from tutors may reflect both policy-level backing and a pedagogical shift toward digital innovation in design education.

7.9 Results and Discussion

The results from the Mixed Reality (MR) experiment demonstrated significant advantages in integrating MR technologies into architectural education, enhancing students' spatial reasoning, creativity, and collaborative skills. Over the semester-long study, qualitative and quantitative data were gathered to assess the impact of MR on students' learning outcomes, focusing on creativity, communication, and confidence in handling complex design projects.

7.9.1 Creativity

The impact of Mixed Reality (MR) on students' creative thinking was supported by both questionnaire responses and interview feedback. Students reported that the ability to shift between VR and AR environments allowed them to rapidly test and refine their ideas during the design process. For example, in post-session reflections, students noted that seeing their designs in both immersive and context-aware formats helped them "come up with ideas I wouldn't have considered in 2D or on paper."

This aligns with findings in Chapter 3, where immersive platforms were associated with enhanced creative exploration by supporting dynamic, iterative workflows (Abdelhameed, 2011; Oxman, 2008). MR's capacity to blend conceptual modeling (in VR) with real-world overlays (via AR) allowed students to shift between abstract and applied thinking — a flexibility that is often constrained in traditional CAD-based methods.

The integration of both digital and physical elements within the design process enhanced creative exploration by offering a more flexible platform where students could visualize their designs in both the conceptual and practical phases of development.

Key Insights:

- Interview Evidence:
 - Several students reported that the immersive MR environment allowed them to iterate more freely on their designs. One student explained:

“When I could walk through and see my structure in AR, it helped me spot things I missed in VR. I went back and made changes straight away.”
 - This iterative switching between digital modes (VR for conceptual ideation, AR for contextual refinement) was consistently noted as a catalyst for more fluid experimentation.
- Observed Trends (Quantitative Data):
 - In the post-experiment questionnaire, 84% of students rated MR’s impact on their creativity as ‘Strongly Positive’, with many citing the speed and clarity of visual feedback as a key factor in pushing their designs further.
- Supporting Literature:
 - These findings align with Angulo et al. (2015), who found that immersive environments, particularly those supporting real-time interaction, bridge the mental divide between abstract and applied design thinking. The present experiment mirrors these outcomes, with MR enabling students to test forms, materials, and structural decisions in a manner that feels immediate and spatially grounded

These findings are also supported by previous studies (Huanget al., 2018) that suggested MR’s ability to enhance creative output by providing real-time feedback, allowing for

rapid ideation and iteration. In line with the previous discussions in Chapter 3 on immersive technologies (Sections 3.8 and 3.9), the potential for MR to revolutionize creativity in architectural education was strongly confirmed by the data.

7.9.2 Communication

Communication emerged as one of the most significantly enhanced aspects of the design process through MR technology. The integration of both VR and AR tools facilitated real-time interactions between students and instructors, allowing them to collaboratively assess design elements in both digital and physical contexts.

Key Findings:

- Interview Evidence (Tutors and Students):
 - Tutors expressed that MR improved their ability to deliver feedback intuitively and spontaneously. One tutor noted:

“Being able to rotate or move parts of the student’s model while we were both inside the scene made my feedback more precise and immediate.”
 - Students highlighted the benefit of peer-to-peer design critiques in MR, stating that the shared immersive space made it easier to identify spatial issues and suggest design alternatives.
 - A student remarked: “I could actually show my idea instead of trying to explain it. That helped me understand and help others better, too.”

- Observed Trends (Quantitative Data):
 - Communication scores (based on pre- and post-experiment questionnaires) increased from an average of 3.5 to 4.4 among students.
 - 70% of students rated the collaborative aspect of MR as 'Very Effective' in enhancing peer discussions during group reviews.
- Supporting Literature:
 - These findings are consistent with Birt et al. (2018), who emphasize the role of AR and MR in enabling real-time shared manipulation of design content, promoting collaborative learning and clearer communication of abstract spatial concepts.
 - Linh (2020) also argues that immersive environments reduce communication barriers by making implicit spatial reasoning more explicit through embodied interaction.

The study aligns with the findings of Bartosh and Anzalone (2019), who indicated that MR environments enhance communication by offering a shared visual platform where students and tutors can engage directly with architectural models. This echoes findings in Chapter 4, where the importance of tools that facilitate direct interaction was highlighted in Sections 4.5.2 and 4.5.3.

7.9.3 Confidence and Competence

As the semester progressed, students demonstrated increased confidence in their use of MR technologies and their ability to handle complex design tasks. Early in the experiment, some participants were hesitant to engage with the MR tools, largely due to the unfamiliarity of the interface. However, through continued use and guided support,

they became more adept at navigating the mixed environment, eventually incorporating MR as an integral part of their design workflow.

Key Insights:

- By the end of the semester, most participants reported that MR significantly boosted their confidence in presenting their designs. This was largely due to the enhanced visual representation offered by MR, allowing them to better communicate their ideas to peers and instructors.
- The hands-on interaction with architectural models in both digital and physical contexts allowed students to gain a deeper understanding of design principles, thereby improving their competence in dealing with real-world architectural challenges.

These findings are consistent with Dorta et al. (2016), who observed that MR significantly improves student confidence by providing a more tactile and immersive learning experience. Chapter 2 (Sections 2.3.10 and 2.3.15) discussed the historical limitations of design tools in fostering student confidence; MR addresses these limitations by making the design process more intuitive and engaging.

7.9.4 Limitations and Challenges

While the MR experiment yielded positive results, certain limitations were identified. Notably, there was a steep learning curve associated with using MR tools, particularly among students with limited prior exposure to digital design platforms. This initially hindered creativity and communication, though these barriers were largely overcome as students became more familiar with the technology.

Challenges Observed:

- **Technical Constraints:** Several participants experienced technical difficulties during the early stages of the experiment, including difficulties with calibration and occasional software glitches.
- **Cost and Accessibility:** As discussed in Chapter 3 (Section 3.4.2), the high cost of MR equipment remains a significant barrier to widespread adoption in architectural education. While the benefits are clear, broader implementation of MR technologies will require significant investment in infrastructure and training.

7.10 Conclusion

The analysis of the three experiments indicates that immersive technologies, including VR, AR, and MR, have a profound positive impact on architectural education. These technologies enhance student engagement, improve communication efficiency, speed up design iterations, and lead to higher quality design outputs. The findings suggest that incorporating immersive technologies into the design curriculum can significantly benefit both students and tutors, fostering a more interactive, efficient, and creative learning environment.

This chapter has provided a comprehensive analysis of the data from the three experiments, with detailed commentary on the results and their implications. The integration of VR, AR, and MR tools in architectural education has shown to be highly effective in enhancing various aspects of the learning and design process. Future research and educational practices should continue to explore and expand the use of these technologies to further improve architectural education and practice.

The Mixed Reality (MR) experiment has provided valuable insights into the impact of MR technologies on architectural education, particularly in terms of creativity, communication, and confidence. Throughout this semester-long study, MR proved to be a transformative tool, blending the strengths of Virtual Reality (VR) and Augmented Reality (AR) into a cohesive and highly interactive platform for design education. The key takeaways from the study are the enhancement of creative exploration, the facilitation of real-time collaboration, and the improvement in students' confidence in employing immersive technologies for architectural design.

Firstly, MR allowed students to integrate their creative ideas across various stages of design development. Unlike VR, which was initially used as a visualization tool in earlier studies, MR's interactive and iterative nature enabled students to dynamically switch between different design stages while maintaining an integrated environment for creative expression. This fostered more innovative and informed decision-making, allowing students to refine their designs through multiple layers of feedback from tutors and peers.

Secondly, MR greatly improved the quality of communication between students and tutors. Real-time feedback, spatial manipulation, and simultaneous interaction with both digital and physical elements provided a collaborative platform where design ideas could be critiqued, revised, and further developed in real-time. This aligns with research from Chapter 3, which highlighted the importance of collaborative learning environments in architectural education (Dorta et al., 2016). The mixed reality environment essentially mirrored professional architectural practices, where collaboration and communication are vital.

Finally, the confidence gained by students in using MR throughout the semester is notable. Many students, initially unfamiliar with immersive technologies, reported increased competence and comfort by the end of the experiment. The extended duration of the MR experiment allowed students to deeply engage with the technology, overcoming the initial technical hurdles and

moving towards more proficient and confident usage of the tools, which Chapter 4 highlighted as a critical outcome of immersive technology integration.

The MR experiment has demonstrated the potential of Mixed Reality as a valuable pedagogical tool in architectural education. Through both quantitative improvements—such as increases in participants’ self-reported creativity, communication, and confidence—and qualitative feedback from interviews and observations, the study showed that MR environments support more interactive and reflective learning experiences. While students expressed that MR helped them visualize, iterate, and discuss their ideas more effectively, there is currently limited direct evidence that these experiences resulted in objectively “better” design outcomes. Rather, the findings suggest that MR facilitated a more dynamic design process, one that may indirectly support better outcomes through deeper engagement and iterative exploration.

Future research should aim to assess design quality more rigorously, for example by comparing project outcomes between students who used MR and those who followed traditional methods, evaluated through tutor grading or expert reviews. Additionally, longitudinal studies would help clarify whether early exposure to MR tools has lasting effects on students’ design capabilities and professional preparedness.

Chapter 8: Research Conclusion

8.1 Review of Research Aim and Objectives

The overarching aim of this research, as outlined in Chapter 1, was to investigate the role of immersive technologies—specifically Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—in enhancing architectural education. This aim was supported by five specific research objectives, each designed to explore how immersive technologies affect creativity, communication, confidence, and competence in design-based learning environments.

In this final chapter, the research aim and objectives are revisited in light of the empirical findings presented in Chapters 5, 6, and 7. This section outlines how each objective was addressed through a combination of literature review, experimental design, questionnaire data, and interview analysis. It also reflects on how the methodology—particularly the use of mixed methods—enabled a comprehensive evaluation of both the potential and challenges of immersive technology integration. The following sections critically assess each objective in turn, linking outcomes directly to the original research framework.

Objective 1: To determine and understand immersive technology's role in enhancing educational outcomes.

The literature review identified numerous benefits of immersive technologies, including enhanced student engagement, improved retention rates, and deeper spatial understanding (Birt et al., 2018; Sánchez-Sepúlveda et al., 2019). As demonstrated in the VR, AR, and MR experiments in Chapters 5, 6, and 7, immersive technologies significantly

improved creativity and communication between students and tutors. These findings align with prior research, indicating that immersive technologies create dynamic, interactive learning environments that go beyond engagement, fostering creativity and collaboration in architectural education (Radi et al., 2021).

Objective 2: To determine and understand existing processes of assessing immersive technology for its educational attributes and use in higher education.

The study revealed that current processes for assessing immersive technologies in educational settings are often limited, particularly in their applicability to architectural pedagogy (Gülden & Tülay, 2021). The literature review, along with the findings from questionnaires and interviews, highlighted that educators often lack the necessary tools to evaluate immersive technology's educational attributes effectively. In Chapter 3, educators expressed the need for comprehensive evaluation tools that account for pedagogical impact rather than just technical features (Dorta et al., 2016). The demand for practical, updated guidance on integrating immersive technologies into educational curricula was evident in the survey results presented in Chapter 6.

Objective 3: To determine educators' awareness of immersive technology and how this understanding is reflected in practice.

Questionnaires and interviews revealed that while educators are generally aware of immersive technologies, many initially struggle to integrate them effectively into their teaching practices (Schön, 1991). Chapters 3 and 6 identified a persistent gap between awareness and implementation, with challenges related to technical skills, limited training, and integration into existing pedagogical structures. However, during the

experiments detailed in Chapters 5, 6, and 7, these challenges appeared to be less pronounced—likely due to the structured nature of the workshops, the availability of technical support, and the relatively short timeframe of the interventions. This suggests that, while institutional and logistical barriers remain significant in broader implementation (Birt et al., 2018), carefully designed and supported short-term interventions can mitigate these obstacles and demonstrate the potential for immersive technologies to be effectively adopted in architectural education.

Objective 4: To critically evaluate educators' challenges in integrating immersive technology into their teaching practices.

The research identified several key challenges educators face when integrating immersive technology into architectural education, including high equipment costs, lack of training opportunities, and limited technical support (Ansar & Khan, 2016). These challenges were not only reflected in the literature but also surfaced during the AR experiment discussed in Chapter 6. For example, in that study, several tutors expressed uncertainty about how to operate the AR tools effectively without prior training, and some participants highlighted that limited access to devices made it difficult to implement AR consistently across larger cohorts. Additionally, the cost of acquiring and maintaining AR-compatible hardware was cited by institutions as a barrier to scaling up these technologies. These findings mirror those in the literature, which point to financial and logistical limitations as ongoing barriers to implementation.

However, the experiments in Chapters 5, 6, and 7 also demonstrated that when these barriers are temporarily mitigated—through the provision of structured training sessions,

focused technical support, and pre-prepared hardware setups—educators were able to integrate immersive technologies meaningfully into their design studio teaching. This suggests that while systemic obstacles remain, they are not insurmountable. With targeted investment in resources and upskilling, these technologies have the potential to significantly improve student engagement and learning outcomes, as also noted in prior studies (Dorta et al., 2016).

Objective 5: To develop practical guidance for educators in selecting immersive technologies based on their educational attributes.

Throughout the study, practical insights emerged regarding how immersive technologies can be evaluated based on their educational impact, not just their technical capabilities (Radi et al., 2021). In particular, the experiments in Chapters 5 (VR), 6 (AR), and 7 (MR) highlighted that the most meaningful benefits of immersive tools were found in how they influenced students' creativity, their ability to communicate design ideas, and their spatial understanding.

For instance, students reported that tools like Gravity Sketch and Shapr3D helped them better visualize and iterate their designs in 3D space, leading to more experimental and refined design outcomes—an indication of increased creative engagement. Communication was also enhanced, as many students and tutors found it easier to express and critique ideas when viewing models immersively rather than relying on 2D drawings or screen-based media. This was reflected in the questionnaire responses, which showed increases in self-reported confidence and clarity during design presentations. Furthermore, spatial understanding was consistently cited in interviews,

where students described how immersive tools helped them grasp proportions, scale, and spatial relationships more intuitively than through traditional methods.

These findings suggest that when educators evaluate immersive technologies, they should prioritise how the tools support these pedagogical dimensions—creativity, communication, and spatial reasoning—rather than focusing exclusively on technical specifications like resolution, frame rate, or software compatibility. A technology might be advanced technically but offer limited educational value if it doesn't actively support student learning. This research offers a framework for making such evaluations more pedagogically meaningful and aligned with the goals of architectural education.

8.2 Reflective Summary

This research has addressed the increasing demand for immersive technologies in educational settings, particularly in architecture, by evaluating their effectiveness in enhancing teaching and learning. Beginning with a comprehensive review of the literature in Chapter 2, the study explored the potential benefits and challenges of immersive technologies in education. . The empirical research conducted through VR, AR, and MR experiments in Chapters 5, 6, and 7 indicated noticeable improvements in student creativity, communication, and confidence. While these enhancements align with the capabilities of immersive technologies as discussed in the literature, it is important to acknowledge that other factors—such as instructor facilitation, participants' prior digital literacy, and the novelty of the technology—may also have contributed to these outcomes. As such, while the results are promising, further

longitudinal studies are needed to isolate the specific impact of immersive technologies from these potentially influential variables.

Chapter 2 highlighted the evolution of architectural pedagogy and the growing role of digital tools (Salama, 2016). It set the stage for understanding how immersive technologies, as examined in this research, could bridge the gap between traditional and modern teaching methods. The findings from the experiments in Chapters 5, 6, and 7 reinforced these insights, showing that immersive technologies offer an engaging, dynamic, and highly effective approach to architectural education (Birt et al., 2018; Gül & Gu, 2019). The study successfully met the objectives set in Chapter 1 and contributed valuable empirical evidence to support the broader integration of immersive technologies in education.

8.3 Contributions to Knowledge

This research has made several key contributions to the body of knowledge in architectural education and immersive technologies. While immersive technologies have been explored in various educational contexts, there has been limited empirical research specifically focusing on how they affect creativity, communication, confidence, and competence in architectural education. This study fills that gap by providing data-driven insights and detailed case studies on the use of VR, AR, and MR in design studios.

Key contributions include:

- **Empirical Evidence:** The research offers a range of empirical data supporting the role of immersive technologies in enhancing student engagement and improving

design outcomes. Specifically, in Chapters 5 (VR), 6 (AR), and 7 (MR), both quantitative and qualitative findings indicated notable improvements in students' creative thinking and communication. For example, post-experiment questionnaire results showed increases in creativity scores (from 3.2 to 4.1 in the VR workshop and 3.2 to 4.3 in the AR workshop), while communication scores improved from 3.5 to 4.4 in the AR workshop. These findings were reinforced through interview feedback, where students reported that immersive tools allowed for greater experimentation, clearer design articulation, and more productive design discussions with peers and tutors.

While these results are promising, the sample sizes (24–57 students across experiments) and relatively short duration of the workshops mean the findings should be interpreted with a degree of caution. There is confidence that the observed improvements are real within the studied context, but further longitudinal studies would be required to generalise the results across broader educational settings. Nonetheless, the triangulation of questionnaire data with interview responses provides a solid foundation to claim that immersive technologies can support key pedagogical outcomes in architectural education.

- **New Insights into Pedagogical Impact:** The study has shown that immersive technologies not only aid in design visualization but also foster deeper collaboration between students and tutors (Dorta et al., 2016). This reflects a broader pedagogical shift towards experiential and interactive learning models, reinforcing theories discussed in Chapters 2 and 3 about the potential of immersive technologies to transform educational practices.

- Practical Guidelines for Educators: Drawing upon the empirical findings from the VR, AR, and MR experiments in Chapters 5 through 7, this research presents practical recommendations for educators seeking to evaluate and integrate immersive technologies into architectural education. Rather than relying solely on technical specifications—such as resolution, frame rates, or device types—the study highlights the importance of selecting tools based on their pedagogical value. Specifically, the tools should be assessed for their ability to:
 - Enhance creativity: as evidenced by student reports of increased freedom to experiment with forms and materials in immersive environments;
 - Support spatial understanding: shown through improvements in students' ability to perceive scale, proportion, and spatial relationships during design reviews;
 - Improve communication: observed through clearer and more confident design presentations and collaborative feedback during immersive sessions.

These conclusions stem directly from both the quantitative improvements recorded in pre- and post-experiment questionnaires (e.g., increased scores in creativity and communication) and qualitative feedback from participants who reflected on how these technologies improved their design learning experience. For instance, students and tutors noted that immersive tools facilitated real-time interaction with 3D models, enabling clearer articulation of design ideas and more iterative feedback loops.

As such, this research contributes actionable guidance for educators: when choosing immersive technologies, priority should be given to tools that align with educational goals, foster active learning, and support reflective practice—core tenets of architectural pedagogy. This shifts the focus away from technical novelty and toward meaningful pedagogical integration.

This research highlights the significant potential of immersive technologies in education, particularly in architectural pedagogy, where the visualization and manipulation of spatial elements are central to the learning process. The insights gained can inform future educational practices and policy decisions, promoting wider adoption of these technologies in architectural education.

8.4 Research Delimitations and Constraints

8.4.1 Delimitations of the Study

The scope of this study was limited to immersive technologies in architectural education, specifically focusing on VR, AR, and MR in design studios. The results are based on a sample of students and educators from select institutions, which may not be fully representative of all educational contexts.

Key delimitations include:

- **Focused Scope:** The research is specific to architectural education and may not directly apply to other disciplines or broader educational settings. While immersive technologies are applicable across various fields, this study

concentrated on their use in design studios, where spatial visualization and collaboration are key (Schön, 1987).

- **Sample Size and Representation:** The participants in this research were selected based on their prior experience with immersive technologies, and the findings reflect their unique perspectives. While the results provide valuable insights, they may not be generalizable to all educators or students in architecture or other disciplines.

8.4.2 Research Constraints

Several constraints were encountered during this research, which impacted its scope and methodology:

- **Technology Access and Costs:** The high cost and limited availability of immersive technology tools constrained the number of participants and institutions that could be included in the study (Ansar & Khan, 2016). This reflects a broader challenge in educational technology adoption, where financial and logistical barriers often limit the scalability of technology-based interventions.
- **Sample Size Limitations:** Obtaining an adequate sample size for each group of professionals and students was challenging due to logistical and technical constraints, particularly the availability of VR/AR/MR hardware and scheduling within academic semesters. While the final sample size enabled meaningful comparative analysis—especially when triangulated with qualitative interviews—it does present limitations in terms of statistical generalizability.

In mixed-methods research, there is no universally fixed minimum sample size, as the adequacy is determined by the research design, the type of analysis conducted, and the saturation point in qualitative inquiry. For the quantitative component of this study, the sample sizes (e.g., VR: 24 students and 6 tutors; AR: 44 students and 6 tutors; MR: 57 students and 6 tutors) align with thresholds used in exploratory studies where inferential statistics such as descriptive analysis and non-parametric testing are employed. Creswell & Plano Clark (2017) suggest that for mixed methods designs, a sample size of at least 30 participants per group can be sufficient for basic statistical interpretation when supported by qualitative insights.

In qualitative research, saturation—the point at which no new themes emerge—is more critical than absolute numbers. According to Guest, Bunce, & Johnson (2006), thematic saturation often occurs within 12–20 interviews in homogeneous participant groups. This study conducted interviews across all three experimental groups, achieving thematic repetition across cohorts, thus supporting the qualitative validity of the findings.

While larger samples would strengthen generalizability, the current sample sizes were sufficient to uncover significant trends, support triangulation, and inform practical insights for architectural education. Future research should aim for broader participant representation to validate and extend these conclusions.

- **Evolving Technology:** Immersive technologies are rapidly evolving, and the tools available at the time of this study may differ from those in future educational

contexts. This rapid development introduces uncertainty when considering the long-term implications of this research. However, the findings remain valuable as they highlight the broader pedagogical trends associated with these tools (Bartosh & Anzalone, 2019).

8.5 Implications for Practice

The findings of this research have significant implications for the practice of architectural education. The integration of immersive technologies into design studios has been shown to enhance student creativity, communication, and spatial understanding, making it an invaluable tool for educators. In this study, creativity was assessed using a combination of self-reported Likert-scale responses in pre- and post-experiment questionnaires, where students evaluated their confidence in generating novel design solutions, as well as qualitative analysis of interview responses and tutor observations. These data points captured changes in students' ability to conceptualize, iterate, and experiment with ideas—core attributes of creativity in architectural education (as also suggested by Abdelhameed, 2011). The combination of numerical scores and thematic insights provided a robust picture of how immersive technologies support creative development.

The following practical recommendations are proposed based on the research findings:

- **Adoption of Immersive Technologies in Design Studios:** Educational institutions should consider integrating immersive technologies into their architectural programs, prioritizing tools that support interactive and experiential learning. As demonstrated in the experiments in Chapters 5, 6, and 7, these tools offer unique

advantages in facilitating design exploration and collaboration (Birt et al., 2018; Speicher et al., 2019).

- **Professional Development for Educators:** While this thesis identifies a lack of widespread expertise and limited pedagogical evidence supporting the implementation of immersive technologies in architectural education, the empirical findings from the VR, AR, and MR experiments suggest promising outcomes in creativity, communication, and confidence. These positive results indicate a need—not for immediate large-scale integration—but for strategically scaffolded professional development. This development should begin with introductory workshops focused on foundational technological skills, then progress to training in pedagogical integration methods, and finally, to collaborative, practice-based inquiry, where educators pilot immersive tools within their own curricula. Institutions can support this progression by allocating resources for continuous professional development and by encouraging knowledge exchange across faculties. This pathway acknowledges the current limitations while offering a realistic route toward adoption, grounded in both technological familiarity and reflective pedagogical practice (Schön, 1991).
- **Institutional Support:** For immersive technologies to be successfully integrated into educational practices, institutions must provide the necessary infrastructure and technical support. This includes ensuring access to VR, AR, and MR tools and offering the technical resources needed to maintain these technologies (Dorta et al., 2016).

8.6 Recommendations for Future Research

While this research has provided valuable insights into the role of immersive technologies in architectural education, it also highlights several areas for future investigation. As immersive technologies continue to evolve and their adoption in education increases, future studies should focus on the following:

- **Longitudinal Studies:** One of the key limitations identified in this research is its relatively short timeframe, which restricted the ability to assess long-term learning outcomes. The findings from the VR, AR, and MR experiments indicate promising short-term improvements in creativity, communication, and confidence, but it remains unclear whether these benefits are sustained over time. As such, a natural extension of this research would be to conduct multi-year longitudinal studies that follow students across their educational journey. These studies could track changes in engagement, retention, design quality, and professional preparedness, providing a more comprehensive understanding of the long-term pedagogical value of immersive technologies. This recommendation arises directly from the questions and limitations identified within the present study, rather than relying on external sources to justify its importance.
- **Broader Educational Contexts:** While this study focused on architectural education, immersive technologies have the potential to impact various other disciplines, such as engineering, medicine, and the arts. Expanding research into these fields would offer a more comprehensive understanding of how these

technologies can enhance learning across different educational domains (Salama, 2016).

- **Technological Advances:** As immersive technologies evolve, new tools and platforms will emerge. Future research should keep pace with these developments, examining the pedagogical implications of emerging technologies such as artificial intelligence (AI)-driven immersive tools and their integration with VR, AR, and MR environments (Gül & Gu, 2019).
- **Institutional and Cultural Contexts:** Research should investigate how different institutional and cultural contexts influence the adoption and effectiveness of immersive technologies. While this study focused on higher education in architecture, broader comparative studies could shed light on the role of immersive technologies in various global educational settings (Ansar & Khan, 2016).

By expanding the scope of research to cover these areas, future studies can build on the findings of this thesis and contribute to the ongoing development of immersive technologies in education.

8.7 Projections

The future of immersive technologies in education, particularly in fields like architecture, is promising. As VR, AR, and MR tools become more sophisticated and accessible, they are expected to revolutionize the way educators and students interact with design concepts and spatial learning.

- **AI and Immersive Technologies:** The integration of AI into immersive technologies holds great potential for enhancing educational practices. AI can support the design process by generating early design concepts, providing real-time data analysis, and automating routine tasks, freeing up educators and students to focus on more creative and strategic aspects of design (Zhang et al., 2018). However, there is also concern that too much automation may reduce creativity. The balance between AI-driven efficiencies and maintaining creative control will be an important focus for future educational models.
- **Widespread Adoption:** Immersive technologies are expected to become more prevalent in educational institutions as their cost decreases and accessibility improves (Dorta et al., 2016). As seen in the experiments conducted in this study, these tools have a transformative impact on design education, fostering creativity, collaboration, and deeper spatial understanding. It is likely that immersive technologies will become a standard part of architectural curricula, blending traditional design approaches with innovative, technology-enhanced methods.
- **Customized Learning Environments:** Immersive technologies enable the creation of customized, student-centered learning environments that can be tailored to individual learning needs. This personalization will enhance student engagement and improve educational outcomes by allowing educators to adapt their teaching methods to suit different learning styles and abilities (Speicher et al., 2019).

In the coming years, immersive technologies and AI will continue to shape architectural education, offering new opportunities for innovation while presenting challenges that will need to be addressed through careful implementation and ongoing research.

8.8 Chapter Summary

This chapter has revisited the primary research objectives set out in Chapter One and provided an evaluation of how they were met through the experiments and analyses conducted in this study. The research aimed to explore the potential of immersive technologies—specifically Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—to enhance architectural education. The experiments conducted in Chapters 5, 6, and 7 demonstrated that immersive technologies can significantly improve creativity, communication, spatial understanding, and student engagement, which are critical aspects of design education.

The literature reviewed in Chapter Two traced the historical evolution of architectural pedagogy, showing the growing importance of incorporating digital tools into design education. Immersive technologies, as discussed throughout the thesis, represent the next step in this evolution, offering educators the ability to create dynamic, interactive learning environments. These technologies help bridge the gap between traditional and digital design processes, providing a platform for students to visualize, manipulate, and iterate their designs more effectively.

The empirical findings from the VR, AR, and MR experiments in Chapters 5, 6, and 7 aligned with the theoretical perspectives discussed in Chapter Three, particularly the benefits of experiential and interactive learning. Immersive technologies allow students to engage more deeply with design concepts, enhancing their ability to understand

spatial relationships and communicate their ideas effectively. These findings reinforce Schön's (1991) theory of "reflection-in-action," highlighting the importance of real-time feedback and iteration in the design process.

One of the key contributions of this research is the demonstration of how immersive technologies can transform the way students and educators interact in design studios. The experiments revealed that these tools foster deeper collaboration, not only between students but also between students and tutors. By allowing students to visualize and manipulate their designs in a 3D environment, immersive technologies promote more meaningful discussions and feedback sessions, as seen in Chapter 6 during the AR experiment.

Despite the overwhelmingly positive results, the research also identified several challenges that must be addressed for immersive technologies to be fully integrated into architectural education. In Chapter 6, during the Augmented Reality (AR) workshop, participants frequently cited technical limitations, such as unstable software and limited device compatibility, as barriers to seamless implementation. Additionally, both students and tutors mentioned that insufficient training made it difficult to fully utilize AR tools, highlighting the need for structured onboarding and ongoing support. Similarly, Chapter 7, which focused on the Mixed Reality (MR) experiment, emphasized the high cost and limited availability of MR hardware, which restricted the number of active users and complicated scheduling for collaborative design sessions. These findings mirror concerns in the literature regarding the accessibility and scalability of immersive technologies in education (Ansar & Khan, 2016; Dorta et al., 2016). Nevertheless, the study demonstrated that when provided with sufficient resources, training, and support,

these challenges can be mitigated, leading to notable improvements in creativity, communication, and student confidence.

In addition to offering practical insights for educators, this research has contributed to the broader body of knowledge by providing empirical evidence on the use of immersive technologies in architectural education. The findings support previous research while also offering new perspectives on the pedagogical benefits of these technologies. The results indicate that immersive tools can enhance not only technical skills but also critical thinking and creativity—two fundamental components of design education.

Finally, this chapter has outlined several areas for future research, suggesting that longitudinal studies and investigations into the broader application of immersive technologies across different educational contexts would provide further valuable insights. As immersive technologies and AI continue to evolve, their role in education will likely expand, creating new opportunities for innovation while also presenting challenges that need to be addressed through careful implementation and ongoing research.

In summary, this research underscores the transformative potential of immersive technologies in architectural education. By enhancing creativity, communication, and spatial understanding, these tools offer a pathway to more effective and engaging learning environments. While there are still hurdles to overcome, the positive results of this study suggest that immersive technologies will play an increasingly important role in shaping the future of design education.

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APPENDICES

Appendix A Questionnaire Template with Tutors (pre experiment VR, AR, MR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (at the email below) in case you have questions.

Participation in the survey is entirely voluntary and you can withdraw at any point in the survey.

The data collected in this survey will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this survey will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the results in the survey will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the survey is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this survey will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this survey study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

We do appreciate that the questionnaire will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please return the completed questionnaire as attachment to the email address below.

Email: Denis.Kolozali@nottingham.ac.uk
Denis Kolozali

Doctoral Research Student

Part I : BACKGROUND

1. 1. Demographics

1.a. Gender

Male ☐

Female ☐

Other ☐

Prefer not to say ☐

1.b. Current Age

1.c. Current Year of Study

2. Years in Architectural Education

a. 1 – 4 years ☐

b. 5 - 10 years ☐

c. 11 - 15 years ☐

d. 16 – 20 years ☐

e. over 20 years ☐

3. Primary Types of Design Tools/Software you Work On: (You can select more than one.)

a. AutoCAD	☐	3Ds Max Studio	☐	Other	☐
b. Revit	☐	Rhino	☐		
c. Sketchup	☐	Manual Drawing/ Handmade	☐		

4. Educational Institutions Attended

IF YOU RECEIVED FORMAL ARCHITECTURAL EDUCATION IN YOUR PROFESSION, WHICH INSTITUTION(S) DID YOU ATTEND?

5. Professional Association Affiliations

IF YOU ARE REGISTERED/CERTIFIED BY YOUR PROFESSIONAL ASSOCIATION, WITH WHICH GROUP ARE YOU AFFILIATED?

Part II: CAD Building Design Awareness and Proficiency**6. How familiar are you with concepts and methods of CAD and CAAD?**

a. Very ☐ b. Somewhat ☐ c. Barely ☐ d. Not at all ☐

7. To what extent are CAAD elements incorporated into the coursework done by your faculty?

a. Every project	☐
b. Most projects	☐
c. A few projects	☐
d. Never	☐

8. How much influence does CAAD have over design studio and design modules?

a. A lot	☐
b. Some	☐
c. Very little	☐
d. None	☐

9. If you received CAD education, to what extent were you educated about virtual building design during your degree or training program?

a. Frequently	☐
b. Occasionally	☐
c. Rarely	☐
d. Never	☐

10. What have been your main sources of information on CAAD education? (Mark up to three.)

a. Personal research	☐
b. Media/articles	☐
c. Continuing ed. Workshops	☐
d. Co-worker	☐
e. Courses	☐
f. Clients	☐

11. If CAAD elements are incorporated into your curriculum, are they incorporated more in design studio- or separate modules?

a. Design Studio	☐
b. Separate modules	☐
c. No difference	☐
b. Don't Know	☐

12. Overall percentage (%) of student design projects you've handled involving CAAD?

a. Less than 10% ☐ b. 10 – 20% ☐ c. 21- 30% ☐ d. > 30%,pls state ☐

13. What portion (%) of Tutors in your university do you think routinely incorporate CAAD into their design studio projects? (Round off to the nearest 5 or 10, i.e., 10%, 15 %...)

14. Think of the most digitally-integrated project you've overseen in design studio. In that project, to what extent were the following types of CAAD considerations and strategies incorporated? (CAD, Digital Graphic Design, Virtual Reality, Augmented Reality, and Holograms, Photography)

<i>Tech Integrated Considerations/Strategies</i>	<i>No measures taken</i>	Used as Design Tool	Used to make Design Decisions
1. CAD: using software to provide 2D or 3D context	☐	☐	☐
2. Digital Graphic Design: using visual editing software such as Photoshop	☐	☐	☐
3. Virtual Reality: use of VR hardware and/or software	☐	☐	☐
4. Augmented Reality: use of AR hardware and/or software	☐	☐	☐
5. Holograms: using hologram tech to provide 3D context	☐	☐	☐
6. Photography: using photographs to provide site context			

Part III: Virtual Reality and/or Augmented Reality in Education

15. How familiar are you with virtual reality and/or augmented reality?

a. Very ☐ b. Somewhat ☐ c. Barely ☐ d. Not at all ☐

16. If you are familiar with VR/AR would you consider using the technology as a teaching tool during design discussion?

a. Yes ☐ b. No ☐

If possible, please give reason(s).....

17. Below is a list of sources of information on VR/AR. Please elaborate on the frequency that you encounter the sources.

	Never	Sometime	Average	Often	Very often
a. Design journals & Magazines	☐	☐	☐	☐	☐
b. Student research projects & Design Studios	☐	☐	☐	☐	☐
c. Research Papers	☐	☐	☐	☐	☐
d. Colleagues	☐	☐	☐	☐	☐
e. Design Exhibitions & fairs	☐	☐	☐	☐	☐
f. Web based information (e.g. internet)	☐	☐	☐	☐	☐
Others(Please specify)	☐	☐	☐	☐	☐

18. Please identify on a scale of 1- 5, from the following statements that best presents your views of VR/AR in architectural academia. (1 =strongly disagree & 5= strongly agree)

	1	2	3	4	5
a. Architectural curriculum should include modules aimed at teaching how to use VR/AR hardware and software	☐	☐	☐	☐	☐
b. There is a growing increase in interest towards teaching with VR/AR	☐	☐	☐	☐	☐
c. VR/AR should be more readily available to students studying architecture	☐	☐	☐	☐	☐
d. Faculties should encourage students to explore VR/AR or any other emerging technologies in their designs.	☐	☐	☐	☐	☐
e. Using VR/AR to teach architectural principles would increase student engagement.	☐	☐	☐	☐	☐
f. VR/AR will eventually be wholly integrated to architectural education.	☐	☐	☐	☐	☐
g. Use of VR and AR tool will open new frontiers as sandbox virtual learning environment.	☐	☐	☐	☐	☐
h. VR sandbox platforms will help students express their creativity more easily.	☐	☐	☐	☐	☐

19. To what extent have the following factors hindered faculty from regularly integrating Virtual Reality and/or Augmented Reality technologies into their design projects?

	Major				Minor
	1	2	3	4	5
a. Lack of information on VR/AR	☐	☐	☐	☐	☐
b. Difficulty in evaluating information	☐	☐	☐	☐	☐
c. Uncertainty in the feasibility for VR/AR based module	☐	☐	☐	☐	☐
d. Training concern	☐	☐	☐	☐	☐
e. Financial restriction	☐	☐	☐	☐	☐
f. Lack of hardware and tools to deliver education material	☐	☐	☐	☐	☐
g. Lack of staff with expertise in the field	☐	☐	☐	☐	☐
h. Limited interest and initiative by faculty students	☐	☐	☐	☐	☐
i. VR/AR does not address the faculty learning outcomes	☐	☐	☐	☐	☐
j. Unwillingness to change the conventional way of teaching	☐	☐	☐	☐	☐
Others (Please specify)	☐	☐	☐	☐	☐

Thank you for completing this survey!

We would like to thank you very much for helping us.

What was this study about?

The survey that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This survey will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education. Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix B Questionnaire Template with Students (pre experiment VR, AR, MR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (at the email below) in case you have questions.

Participation in the survey is entirely voluntary and you can withdraw at any point in the survey.

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If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the survey is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this survey will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

☐ I give permission to collect, store, analyse and publish information obtained from this survey. I give permission to be use data collected in this survey for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected will not be used for commercial purposes. I give permission to use the information collected in this survey, without any obligation to seek further authorisation by me.

☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this survey study.

We do appreciate that the questionnaire will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please return the completed questionnaire as attachment to the email address below.

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Part I : BACKGROUND

1. Demographics

1.a. Gender

Male ☐

Female ☐

Other ☐

Prefer not to say ☐

1.b. Current Age

1.c. Current Year of Study

2. Years in Architectural Education

a. 1 – 4 years ☐

b. 5 - 10 years ☐

c. 11 - 15 years ☐

d. 16 – 20 years ☐

e. over 20 years ☐

3. Primary Types of Design Tools/Software you Work On: (You can select more than one.)

a. AutoCAD	☐	3Ds Max Studio	☐	Other	☐
b. Revit	☐	Rhino	☐		
c. Sketchup	☐	Manual Drawing/ Handmade	☐		

Part II: CAD Building Design Awareness and Proficiency

4. How familiar are you with concepts and methods of CAD and CAAD? (CAD=Computer Aided Design, CAAD=Computer Aided Architectural Design)

a. Very ☐ b. Somewhat ☐ c. Barely ☐ d. Not at all ☐

5. To what extent are CAAD elements incorporated into the coursework done by your faculty?

a. Every project	☐
b. Most projects	☐
c. A few projects	☐
d. Never	☐

6. How much presence does CAAD have over design studio and design modules?

a. A lot	☐
b. Some	☐
c. Very little	☐
d. None	☐

7. If you received CAAD education, to what extent has your education increased your proficiency to design in 3D?

a. Expert	☐		
b. Intermediate	☐		
c. Know the basics	☐	d. Not proficient	☐

8. How often do you use CAD for your design projects?

a. Always	☐
b. Often	☐
c. Sometimes	☐
d. Very rarely	☐
e. Never	☐

9. What have been your main sources of information on CAAD education outside of your curriculum? (Mark up to three.)

a. Personal research	☐
b. Media/articles	☐
c. Online ed. Workshops	☐
d. Course mates	☐
e. Internship	☐

10. If CAAD elements are incorporated into your curriculum, are they incorporated more in design studio- or separate modules?

a. Design Studio	☐
b. Separate modules	☐
c. No difference	☐
b. Don't Know	☐

11. Think of the most digitally-integrated project you've done or seen in design studio. In that project, to what extent were the following types of CAAD considerations and strategies incorporated? (CAD, Digital Graphic Design, Virtual Reality, Augmented Reality, and Holograms, Photography)

<i>Tech Integrated Considerations/Strategies</i>	Not Used	Used as Design Tool	Used to make Design Decisions
1. CAD: using software to provide 2D or 3D context	☐	☐	☐
2. Digital Graphic Design: using visual editing software such as Photoshop	☐	☐	☐
3. Virtual Reality: use of VR hardware and/or software	☐	☐	☐
4. Augmented Reality: use of AR hardware and/or software	☐	☐	☐
5. Holograms: using hologram tech to provide 3D context	☐	☐	☐
6. Photography: using photographs to provide site context			

Part III: Virtual Reality and/or Augmented Reality in Education

12. How familiar are you with virtual reality and/or augmented reality?

a. Very ☐ b. Somewhat ☐ c. Barely ☐ d. Not at all ☐

13. If you are familiar with VR/AR would you consider using the technology in the design studio during design discussion?

a. Yes ☐ b. No ☐

If possible, please give reason(s).....

14. Below is a list of sources of information on VR/AR. Please elaborate on the frequency that you encounter the sources.

	Never	Sometime	Average	Often	Very often
a. Design journals & Magazines	☐	☐	☐	☐	☐
b. Student research projects & Design Studios	☐	☐	☐	☐	☐
c. Research Papers	☐	☐	☐	☐	☐
d. Colleagues	☐	☐	☐	☐	☐
e. Design Exhibitions & fairs	☐	☐	☐	☐	☐
f. Web based information (e.g. internet)	☐	☐	☐	☐	☐
g. Social Media	☐	☐	☐	☐	☐
Others(Please specify)	☐	☐	☐	☐	☐

15. Please identify on a scale of 1- 5, from the following statements that best presents your views of VR/AR in architectural academia. (1 =strongly disagree & 5= strongly agree)

	1	2	3	4	5
a. Architectural curriculum should include modules aimed at teaching how to use VR/AR hardware and software	☐	☐	☐	☐	☐
b. There is a growing increase in interest towards teaching with VR/AR	☐	☐	☐	☐	☐
c. VR/AR should be more readily available to students studying architecture	☐	☐	☐	☐	☐
d. Faculties should encourage students to explore VR/AR or any other emerging technologies in their designs.	☐	☐	☐	☐	☐
e. Using VR/AR to teach architectural principles would increase student engagement.	☐	☐	☐	☐	☐
f. VR/AR will eventually be wholly integrated to architectural education.	☐	☐	☐	☐	☐
g. Use of VR and AR tool will open new frontiers as interactive virtual learning environment.	☐	☐	☐	☐	☐
h. VR/AR interactive platforms will help students express their creativity more easily.	☐	☐	☐	☐	☐

Thank you for completing this survey!

We would like to thank you very much for helping us.

What was this study about?

The survey that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This survey will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education. Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

[Denis Kolozali](#) – 2023

Appendix C Questionnaire Template with Tutors (post experiment VR)

Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

[Denis Kolozali](#) – 2022

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk
Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. How did using VR for a design discussion impact your evaluation of student design ideas?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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2. While engaging in design discussion with VR, how did you feel about the impact it may have had on student creativity?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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3. During the design tutorials how did you feel about your abilities to deliver the learning outcomes?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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4. Having done an induction prior to the experiment how do you feel about your control and mastery over the technology?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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5. How do you feel about the retention of discussions with your student during your design tutorial?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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6. Can you describe your attitudes and approach to working with your student in virtual space?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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7. When compared with how design tutorials are regularly taught at your university, how does the new approach differ?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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8. If given the chance to utilise this approach in your next design module at which stage would you picture yourself using this approach? And why?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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9. What stood out to you as the defining characteristic of virtual collaborative design with your student?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive
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10. Having experienced a design tutorial in virtual space, if given the chance again, how do you feel about utilising it in your academic career?
☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive
.....
11. How did your experience with virtual design studio make you feel about student's reflection of their own design?
☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive
.....

The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix D Questionnaire Template with Students (post experiment VR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

- ☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.
- ☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.
- ☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.
- ☐ I understand that data from this study will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.
- ☐ I give permission to collect, store, analyse and publish information obtained from this study. I give permission to be use data collected in this study for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected will not be used for commercial purposes. I give permission to use the information collected in this study, without any obligation to seek further authorisation by me.
- ☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.
- ☐ I agree to take part in this study.
-

**RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE
ARCHITECTURAL FACULTIES OF CYPRUS**

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. How did using VR for a design discussion impact your perception of expressing design ideas?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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2. While engaging in design discussion with VR, how did you feel about the impact it may have had on your creativity?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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3. During the design tutorials how did you feel about your abilities to communicate ideas across?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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4. Having done an induction prior to the experiment how do you feel about your control and mastery over the technology?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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5. How do you feel about the retention of discussions with your tutor during your design tutorial?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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6. Can you describe your attitudes and approach to working with your tutor in virtual space?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

7. When compared with how design tutorials are regularly taught at your university, how does the new approach differ?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

8. If given the chance to utilise this approach in your next design module at which stage would you picture yourself using this approach? And why?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

9. What stood out to you as the defining characteristic of virtual collaborative design with your tutor?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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10. Having experienced a design tutorial in virtual space, if given the chance again, how do you feel about utilising it in your academic future or career?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix E Questionnaire Template with Tutors and Students (update pre experiment AR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I understand the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this study will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. Please identify the scale of 1- 5, from the following statements that best presents your awareness of VR in design studio. (1 =strongly disagree & 5= strongly agree)

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
i. <u>Use of VR in education should expand more than design considerations</u>					
j. <u>Guides for learning to use VR can be easily accessible in Cyprus</u>					
k. <u>Virtual Reality considerations serve mainly as visualization tools</u>					
l. <u>Adopting VR design should be an available option</u>					
m. <u>Use of virtual environment and user-friendly VR will help to provide more natural learning experience.</u>					
n. <u>That VR is getting more recognition among my colleagues and co-workers.</u>					
o. <u>I believe that using user friendly virtual learning environment will increase engagement and retention.</u>					
p. <u>An increase in the focus and memory of design sessions.</u>					
q. <u>I have noticed that my classmates intend to incorporate VR in future modules</u>					
r. <u>It is important for aspiring architects to be conscious that some of the VR design aspects have an impact on the learning environment</u>					
s. <u>It is important for aspiring architects to consider the full range of educational impacts of virtual learning environments by assessing their stimulus on creativity</u>					

2. To what extent have the following factors affect tutors and students from regularly integrating VR into their projects? Please include any barriers to VR uptake.

	<u>Minor</u>				<u>Major</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
k. <u>Information on VR design learning materials</u>					
l. <u>Evaluating information</u>					
m. <u>Liability for the final works</u>					
n. <u>Maintenance concern</u>					
o. <u>Lack of tools and data to compare method alternatives</u>					
p. <u>Time being sustained</u>					
q. <u>Balancing environmental, economic & technical factors</u>					
r. <u>The impact of VR designs on project quality</u>					
s. <u>Attractiveness and interest in introducing VR to architectural design</u>					
t. <u>Flexibility for alternatives of the proposed ideas when using VR</u>					
u. <u>Desire to change the conventional way of teaching</u>					
<u>Others (Please specify)</u>					

3. Please indicate how each of the following factors influence the use of the tools in design discussions (Please tick box as appropriate; 1 = Not frequent to 5 = Most frequent)

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
<u>a. Familiarity with the technique</u>					
<u>b. Cost involved in its use</u>					
<u>c. Time taken in using technique</u>					
<u>d. Skills in using technique</u>					
<u>e. Suitable programming software</u>					
<u>g. Adequate project information</u>					
<u>Others (Please specify)</u>					

Part IV: VIEWS

4. How do the following factors influence your faculty incorporating VR strategies into their design project? Please elaborate on any additional factors that you list.

<u>BARRIERS</u>	<u>Minor</u>	<u>Neutral</u>	<u>Major</u>
<u>1. Expressed interest from tutors</u>			
<u>2. Training/education in VR design</u>			
<u>3. VR design options and ability (opportunity)</u>			
<u>4. Technical understanding on the part of faculty members</u>			
<u>5. Technical understanding on the part of fellow students on the design project</u>			
<u>6. Interest from faculty members on the design project</u>			
<u>7. Availability on learning materials such as tutorials</u>			
<u>8. Information on VR design courses/methods</u>			

5. What ideas, people, or events were most effective in developing your interest in designing with VR?

a. People/groups
b. Publications:
c. Experiences:
d. Events:

6. If any VR strategies have been incorporated into your design projects, which (if any) faculty modules or programs contributed to the decision to do so?

Economic incentives:

Educational programs:

Regulatory requirements:

Voluntary guidelines:

7. What sorts of programs would make it easier for you to become more involved in incorporating VR strategies into your design projects in the future?

Economic incentives:

Educational programs:

Regulatory requirements:

VR design guidelines and education standards:

Thank you for your interest. And thank you to all those who submitted responses to the questionnaire.

The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix F Questionnaire Template with Tutors (post experiment AR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this study will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

☐ I give permission to collect, store, analyse and publish information obtained from this study. I give permission to be use data collected in this study for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected will not be used for commercial purposes. I give permission to use the information collected in this study, without any obligation to seek further authorisation by me.

☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. How did using VR for a design discussion impact your evaluation of student design ideas?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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2. While engaging in design discussion with VR, how did you feel about the impact it may have had on student creativity?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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3. During the design tutorials how did you feel about your abilities to deliver the learning outcomes?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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4. Having done an induction prior to the experiment how do you feel about your control and mastery over the technology?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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5. How do you feel about the retention of discussions with your student during your design tutorial?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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6. Can you describe your attitudes and approach to working with your student in virtual space?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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7. When compared with how design tutorials are regularly taught at your university, how does the new approach differ?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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8. If given the chance to utilise this approach in your next design module at which stage would you picture yourself using this approach? And why?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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9. What stood out to you as the defining characteristic of virtual collaborative design with your student?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive
10. Having experienced a design tutorial in virtual space, if given the chance again, how do you feel about utilising it in your academic career?
☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive
11. How did your experience with virtual design studio make you feel about student's reflection of their own design?
☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix G Questionnaire Template with Students (post experiment AR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this study will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

**RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE
ARCHITECTURAL FACULTIES OF CYPRUS**

Email: Denis.Kolozali@nottingham.ac.uk
Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. How did using VR for a design discussion impact your perception of expressing design ideas?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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2. While engaging in design discussion with VR, how did you feel about the impact it may have had on your creativity?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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3. During the design tutorials how did you feel about your abilities to communicate ideas across?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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4. Having done an induction prior to the experiment how do you feel about your control and mastery over the technology?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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5. How do you feel about the retention of discussions with your tutor during your design tutorial?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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6. Can you describe your attitudes and approach to working with your tutor in virtual space?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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7. When compared with how design tutorials are regularly taught at your university, how does the new approach differ?

☐ Strongly Negative
 ☐ Negative
 ☐ Neutral
 ☐ Positive
 ☐ Strongly Positive

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8. If given the chance to utilise this approach in your next design module at which stage would you picture yourself using this approach? And why?

☐ Strongly Negative
 ☐ Negative
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 ☐ Positive
 ☐ Strongly Positive

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9. What stood out to you as the defining characteristic of virtual collaborative design with your tutor?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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10. Having experienced a design tutorial in virtual space, if given the chance again, how do you feel about utilising it in your academic future or career?

☐ Strongly Negative ☐ Negative ☐ Neutral ☐ Positive ☐ Strongly Positive

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The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix H Questionnaire Template with Tutors (mid experiment MR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

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Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. Overall Experience with Students' Use of VR and AR: On a scale of 1 to 5, please rate the overall experience you observed in students' use of VR and AR technologies during this week's session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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2. Impact on Students' Creativity: On a scale of 1 to 5, rate the extent to which you believe the use of VR and AR technologies enhanced students' creativity in architectural design this week. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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3. Impact on Students' Learning Experience: On a scale of 1 to 5, rate how you believe the use of VR and AR technologies improved students' learning experience in architectural design this week. Please provide any observations you made.				
Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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4. Technical Challenges Faced by Students: a. Did students encounter any notable technical challenges while using VR and AR technologies this week? b. If yes, please provide a brief description of the technical challenges observed. Please provide any observations you made.				
Yes		No		
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5. Perception of Students' Learning Efficiency: On a scale of 1 to 5, rate your perception of how efficiently students were able to understand and implement architectural concepts using VR and AR technologies. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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6. Impact on Students' Collaboration and Communication: On a scale of 1 to 5, rate how the use of VR and AR technologies influenced collaboration and communication among students during this week's design project. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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7. Usability and User-Friendliness of VR and AR Technologies: On a scale of 1 to 5, rate your perception of the usability and user-friendliness of the VR and AR technologies used during this week's session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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8. Comparison with Traditional Methods: a. In your opinion, how did the use of VR and AR technologies compare to traditional design methods in enhancing students' understanding of design discussion? b. Please provide specific aspects where you found VR and AR technologies to be more or less effective than traditional methods for students' understanding of spatial relationships and design elements.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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9. Immersive Learning Experience: On a scale of 1 to 5, rate the level of immersion and engagement you observed in students' learning experiences using VR and AR technologies this week. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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10. Impact on Students' Design Iteration and Refinement: On a scale of 1 to 5, rate how effectively VR and AR technologies facilitated students' design iteration and refinement during this week's session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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11. Perception of Students' Visualization Abilities: a. How did the use of VR and AR technologies impact students' ability to visualize their design concepts, in your observation? b. Please provide details on how the use of VR and AR technologies affected students' visualization of design concepts, based on your observation.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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12. Perception of Students' Time Management: On a scale of 1 to 5, rate how effectively students managed their time using VR and AR technologies during the design session, in your observation. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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13. Integration of VR and AR Technologies: a. As a tutor, do you believe the integration of VR and AR technologies was beneficial or a drawback or neutral for students' overall understanding of architectural design concepts? b. Please rate the amount of your choice and share your reasons for believing in the benefits or drawbacks or no difference when integrating VR and AR technologies in architectural design education.

a)	Beneficial	Neutral	Drawback

b)	Very Low	Low	Average	High	Very High

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Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix I Questionnaire Template with Students (mid experiment MR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this study will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. Overall Experience with VR and AR: On a scale of 1 to 5, please rate your overall experience using VR and AR technologies during this week's session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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2. Impact on Creativity: On a scale of 1 to 5, rate how you believe the use of VR and AR technologies enhanced your creativity in architectural design this week. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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3. Impact on Learning Experience: On a scale of 1 to 5, rate how you believe the use of VR and AR technologies improved your learning experience in architectural design this week. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive

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4. Technical Challenges: Did you encounter any technical challenges while using VR and AR technologies this week? If yes, please briefly describe the technical challenges you faced. Please provide any observations you made.

Yes	No

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5. Learning Efficiency: On a scale of 1 to 5, rate how efficiently you were able to understand and implement architectural concepts using VR and AR technologies. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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6. Collaboration and Communication: On a scale of 1 to 5, rate how VR and AR technologies influenced collaboration and communication among peers during this week's design project. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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7. Usability and User-Friendliness: On a scale of 1 to 5, rate the usability and user-friendliness of the VR and AR technologies used during this week's session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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8. Comparison with Traditional Methods: a. In comparison to traditional design methods, do you believe using VR and AR technologies enhanced your understanding of design discussion? b. Please provide specific aspects where you found VR and AR technologies more beneficial than traditional methods.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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9. Immersive Learning Experience: On a scale of 1 to 5, rate how immersive and engaging the use of VR and AR technologies was for your learning experience this week. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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10. Design Iteration and Refinement: On a scale of 1 to 5, rate how effectively VR and AR technologies facilitated design iteration and refinement during this week's design session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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11. Impact on Visualization: a. How did using VR and AR technologies impact your ability to visualize your design concepts? b. Please provide details on how using VR and AR technologies affected your visualization of design concepts.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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12. Perception of Time Management: On a scale of 1 to 5, rate how effectively you managed your time using VR and AR technologies during the design session. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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13. Future Use and Interest: a. Would you be interested in using VR and AR technologies in future design sessions? b. Please share reasons for your interest or lack of interest in using VR and AR technologies in future design sessions.

Yes

No

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The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix J Questionnaire Template with Tutors (post experiment MR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

[Denis Kolozali](#) – 2023



Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

☐ I understand that data from this study will be stored in a secure location in accordance with University of Nottingham regulations, including the new General Data Protection Regulation (GDPR) that came into force in May 2018.

☐ I give permission to collect, store, analyse and publish information obtained from this study. I give permission to be use data collected in this study for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected will not be used for commercial purposes. I give permission to use the information collected in this study, without any obligation to seek further authorisation by me.

☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. How did using VR/AR for a design discussion impact your evaluation of your student's confidence in design ideas? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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2. While engaging in design discussion with VR/AR, how did you feel about the impact it may have had on student creativity? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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3. During the design tutorials how did you feel about your abilities to communicate with the student in regards to delivering the learning outcomes? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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4. Having done an induction prior to the experiment how do you feel about your control and mastery over the design discussion within the virtual environment? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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5. How do you feel about the level of retention/memory from the discussions with your student during your design tutorial with enhanced reality as oppose to the traditional way? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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6. Can you describe differences in your attitudes and approach to working with your student in virtual space when compared with traditional methods? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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7. When compared with how design tutorials are regularly taught at your university, to what extent does the new approach differ when students are trying to express their creative side? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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8. If given the chance to utilise this approach in your next design module at which stage would you picture yourself using this approach? And why?

Analysis	Concept	Design	Detailing	Presentation
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9. What stood out to you as the defining characteristic of virtual collaborative design with your student? And how would you rate them?

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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10. Having experienced a design tutorial in virtual space, if given the chance again, how do you feel about utilising it in your academic and/ or professional career? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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11. How did your experience with virtual design studio make you feel about student’s retention of the discussion in regards to reflection of their own design ideas? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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12. In your opinion, which of the following role or roles did VR/AR impact the creativity in student's architectural design? (Select all that apply). Please provide any observations you made.

- Generating innovative design solutions

- Incorporating unique and original ideas

- Enhancing user experience and functionality

- Pushing boundaries and challenging conventions

- Creating aesthetically pleasing designs

- Other (please specify)

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13. How would you rate the level of support and resources for exploring architectural design with virtual reality (VR) and augmented reality (AR) applications. Please provide any observations you made.

Strongly Negative Negative Neutral Positive Strongly Positive

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14. Which of the following aspects of architectural design do you find VR/AR was most stimulating in terms of fostering student creativity? (Select all that apply). Please provide any observations you made.

- Concept development and ideation

- Spatial planning and organization

- Material and construction exploration

- Integration of technology and innovation

- Cultural and contextual considerations

- Other (please specify)

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15. Describe and rate a part of the design discussion while using VR/AR, where you may have felt student creativity was expressed to its limits. What made it challenging, and how did you overcome it?

Rarely or Never

Occasionally

Sometimes

Often

Very Often

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16. Rate your level of agreement with the following statement: "Creativity in architectural design can be enhanced through deliberate practice and exposure to diverse design experiences." Please provide any opinions you may have.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
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17. To what extent does your architectural education program might encourage integrating VR/AR to critical thinking and problem-solving skills in the design process in the future? Please provide any observations you made.

Very little Extent	Some Extent	Moderate Extent	High Extent	Full Extent
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18. To what extent does your architectural education program encourage experimentation and risk-taking in design solutions? Such as this experiment. Please provide any observations you made.

Very little Extent	Some Extent	Moderate Extent	High Extent	Full Extent
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19. How frequently are students in your architectural education program encouraged to present their design ideas through new and unorthodox methods of visual presentations and verbal communication? Such as the one you have used in this experiment. Please provide any observations you made.

Rarely or Never Occasionally Sometimes Often Very Often

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20. How well does your architectural education program encourage the integration of VR/AR experimentation and iteration in the design process?. Please provide any observations you made.

Poorly Below Average Average Above Average Excellent

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21. How would you rate the level of adaptability and responsiveness of your architectural education program to the evolving trends and technologies in the field of architecture? Please provide any observations you made.

Strongly Negative

Negative

Neutral

Positive

Strongly Positive

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The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix K Questionnaire Template with Students (post experiment MR)



Participation Information Sheet

Please take time to read the following information carefully. Feel free to discuss with the researcher (in person or at the email below) in case you have questions.

Participation in the study is entirely voluntary and you can withdraw at any point in the study.

The data collected in this study will be used for anonymous statistical analysis and, eventually, for publication in academic journals and international conferences. The use of the information provided may include editing, duplication, and incorporation in other works such as posters, papers, conference presentation and websites. The information collected in this study will not be used for commercial purposes. In all instances, your participation will remain anonymous and confidential and the recordings in the study will be attributed to the researcher. The raw data will be stored in a secure location in accordance with University of Nottingham regulations, including the General Data Protection Regulation (GDPR) that came into force in May 2018.

If you would like to know more about the study or have any questions you can contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk) for further information. A debrief sheet will be provided at the completion of the questionnaire giving more information on the study's aims.

Please read carefully and tick all the boxes.

☐ I confirm that I have read and understood the information sheet for this study and have had the opportunity to ask questions via email.

☐ I understand that all personal information will remain confidential and that all efforts will be made to ensure I cannot be identified.

☐ I declare the information shared in the study is entirely mine and will not hold any identifiable information of another individual or individuals, e.g. faces, address, car license plates.

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☐ I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason, and without any legal rights being affected.

☐ I agree to take part in this study.

RESEARCH INTO ROLE OF COMPUTER AIDED ARCHITECTURAL DESIGN / CAAD IN THE ARCHITECTURAL FACULTIES OF CYPRUS

Email: Denis.Kolozali@nottingham.ac.uk

Denis Kolozali

Doctoral Research Student

Expected Average Interview time range per person: 8-12mins

Opening Statement:

We do appreciate that the interview will take some of your valuable time but without your kind and expert input the research objectives aimed at improving architectural education cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration. Please note that you can ask, at any time during the interview to stop for any reason or request your record to be deleted.

1. How did using VR/AR for a design discussion impact your evaluation of your own confidence in design ideas? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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2. While engaging in design discussion with VR/AR, how did you feel about the impact it may have had on your creativity? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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3. During the design tutorials how did you feel about your abilities to communicate with your tutor in regards to the learning outcomes? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
..... 				
4. Having done an induction prior to the experiment how do you feel about your control and mastery over the design discussion within the virtual environment? Please provide any observations you made.				
Strongly Negative	Negative	Neutral	Positive	Strongly Positive
..... 				
5. How do you feel about the level of retention/memory from the discussions with your tutor during your design tutorial with enhanced reality as oppose to the traditional way? Please provide any observations you made.				
Strongly Negative	Negative	Neutral	Positive	Strongly Positive
..... 				
6. Can you describe differences in your attitudes and approach to working with your tutor in virtual space when compared with traditional methods? Please provide any observations you made.				

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
..... 				
7. When compared with how design tutorials are regularly taught at your university, to what extent does the new approach differ when trying to express your creative side? Please provide any observations you made.				
Strongly Negative	Negative	Neutral	Positive	Strongly Positive
..... 				
8. If given the chance to utilise VR/AR approach in your next design module at which stages would you picture yourself using this approach? And why?				
Analysis	Concept	Design	Detailing	Presentation
..... 				
9. How frequently are students in your architectural education program encouraged to present their design ideas through new and unorthodox methods of visual presentations and verbal communication? Such as the one you have used in this experiment. Please provide any observations you made.				

Rarely or Never	Occasionally	Sometimes	Often	Very Often
.....				
10. How well does your architectural education program encourage the integration of VR/AR experimentation and iteration in the design process? Please provide any observations you made.				
Poorly	Below Average	Average	Above Average	Excellent
.....				

11. How would you rate the level of adaptability and responsiveness of your architectural education program to the evolving trends and technologies in the field of architecture? Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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12. In your opinion, which of the following role or roles did VR/AR impact the creativity in your architectural design? (Select all that apply). Please provide any observations you made.

- Generating innovative design solutions	
- Incorporating unique and original ideas	
- Enhancing user experience and functionality	
- Pushing boundaries and challenging conventions	
- Creating aesthetically pleasing designs	
- Other (please specify)	
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13. How would you rate the level of available support and resources for exploring architectural design with virtual reality (VR) and augmented reality (AR) applications. Please provide any observations you made.

Strongly Negative	Negative	Neutral	Positive	Strongly Positive
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14. Which of the following aspects of architectural design do you find VR/AR was most stimulating in terms of fostering creativity? (Select all that apply). Please provide any observations you made.

- Concept development and ideation	
- Spatial planning and organization	
- Material and construction exploration	
- Integration of technology and innovation	
- Cultural and contextual considerations	
- Other (please specify)	
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15. Describe and rate a part of the design discussion while using VR/AR, where you may have felt your creativity was expressed to its limits. What made it challenging, and how did you overcome it?

Rarely or Never	Occasionally	Sometimes	Often	Very Often
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16. Rate your level of agreement with the following statement: "Creativity in architectural design can be enhanced through deliberate practice and exposure to diverse design experiences."

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
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17. To what extent does your architectural education program might encourage integrating VR/AR to critical thinking and problem-solving skills in the design process in the future? Please provide any observations you made.

Very little Extent	Some Extent	Moderate Extent	High extent	Full extent
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18. To what extent does your architectural education program normally encourage experimentation and risk-taking in design solutions? Such as this experiment. Please provide any observations you made.

Very little Extent	Some Extent	Moderate Extent	High extent	Full extent

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The interview that you completed is part of a larger study designed to test potential of integrating emerging technologies such as VR/AR into architectural pedagogy. This research will contribute towards a database of awareness towards emerging technology that will be employed in academic research. The database may be made publicly available online for future researchers. You also provided pertinent information related to the research on VR/AR architectural education.

Thank you.

For further enquiries, please contact: Denis Kolozali, Denis.Kolozali@nottingham.ac.uk

Appendix L Ethics Approval for VR Experiment

Faculty of Engineering

Process for approval of research study involving human participants

Introduction

This document describes the process to be followed when planning and obtaining approval for studies involving human participants within the Faculty of Engineering. This process is based on one previously run within the School/Dept M3. The process is administered by the Faculty Research Ethics Committee, and managed by the Chair of the Ethics Committee, Dr. Robert Houghton, and Faculty Research Ethics Officer, Prof. Sarah Sharples. All queries regarding the process should be initially sent to the Faculty Ethics Administrator, Donna Astill-Shipman.

What is Ethics Approval?

When conducting any study or observation or collecting data about individuals, it is essential that full consideration is given to ethical issues and that steps are taken to ensure participant well-being throughout the study.

Participants involved in research studies have a right to:

- Know the goals of the study and who is funding the work
- Make an informed decision about whether or not they wish to participate
- Leave the study at any time if they do not wish to continue
- Know what will happen to them during the study and how long it will take
- Know if they may experience any discomfort
- Know what will happen to the findings
- Privacy of personal information
- Be treated courteously

The University of Nottingham and Faculty of Engineering have an ethics procedure that requires all staff and students to submit an application for ethical approval before conducting any research study involving human participants. Members of the Ethics Committee read through study proposals to check that the researcher has demonstrated that they have given full consideration to ethical issues and that they have provided participants with appropriate and sufficient information.

Who needs Ethics Approval?

ANY member of staff or registered student of the University of Nottingham involved in conducting any study or observation or collecting data about individuals **MUST** adhere to the University Code of Research Conduct and Research Ethics. Those affiliated with the Faculty of Engineering **MUST ALSO** comply with the Faculty ethical approval process before commencing their study.

Ethics application procedure

The attached document outlines the ethics approval process within the Faculty of Engineering. For all applications required to undergo formal review, applications must be submitted to the **Ethics Administrator**, [email: ez-eng-ethics]. The application will then be reviewed by the ethics committee. We aim to return a decision to applicants within two weeks but the procedure may be delayed if the ethics committee require further information. It is the applicant's responsibility to make sure that applications are submitted in good time. **THE STUDY MAY NOT START UNTIL ETHICAL APPROVAL HAS BEEN AWARDED**

Information you should give to ALL participants

The following list describes the information that should be given to all participants. Normally this should be given in a participant information sheet at the beginning of the study, and participants should be required to confirm that they have understood the nature of the study, and that they are happy to participate.

The following information should be included:

Details of who will be conducting the study.

Details about who is sponsoring the study and what the terms of the sponsorship are (i.e. who will 'own' the data and how the data will be used).

Details about the nature, purpose and duration of the study. (Participants whose first language is NOT English may need further explanation of what is involved as their understanding of some of the terminology may be limited).

What kinds of procedures will be used and what participant will be asked to do.

Details about any hazards, inconveniences and risks associated with the study.

What procedures will be followed if a participant is injured. (only needed if risk of injury has been identified)

What benefits (payments, expenses etc) are attached to the study.

What they need to do in order to receive the payments described above.

What procedures will be employed to maintain confidentiality and anonymity (e.g. removing personal details from data/reports, keeping data in locked files)

What will happen to the data (how it will be used, how it will be stored, in what form it will be disseminated and if it is likely to be used for further analysis).

How you will use photographs or video records (data analysis, illustration purposes, displayed to sponsors/ non-public academic audiences, printed in public domain documents etc).

Details about who to contact if questions or problems arise.

ALL participants must be told that any involvement in the study is voluntary and they are free to withdraw at any time. You should also explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

Faculty of Engineering

Application for approval of research study involving human participants

ALL applicants must provide the following information

The applicant must be the person who will conduct the investigations; each application must be made by one applicant:

usually the student in the case of taught or research courses,

usually the researcher (the member of university research or academic staff) who will conduct the study in the case of funded research projects,

usually the principal investigator in the case of applications for ethics approval in advance of submission of a research proposal

If the applicant is an Undergraduate or Postgraduate taught or research student please complete the information below. The application must be approved by a Supervisor.

Name of student:	Denis Kolozali	Student No:	4299912
Course of study:	PhD Architecture	Email address:	Denis.Kolozali@nottingham.ac.uk
Supervisor:	Dr. Peter Rutherford	PGR ☒	
	Dr. Glynn Lawson		
		MSc ☐	

If the applicant is a member of university research or academic staff, please complete the information below: For research staff, the application must be approved by the Principal Investigator

Name:		Principal Investigator	
		(Budget Holder)	
Email address:		PI Signature:	

Title of investigation: Visual Scene Preference

Planned date for study to begin 04-August-2022.....Duration of Study 2 weeks

Please state whether this application is:

New ☒ Revised ☐ A renewal ☐ For a continuation study ☐

Selection of review process

Please indicate whether the application is required to go forward to the ethics committee for formal review, or, in the case of projects completed by ***taught undergraduate and postgraduate students only***, whether the application can be approved by the supervisor under the expedited review process*.

☐ Formal review, application will be
by supervisor*

submitted to ethics committee
is a

☐ Expedited review, application is approved

* ☐ option can only be selected if the Supervisor

is a member of the Faculty Ethics committee

Approval by supervisor: expedited review

I approve the application as supervisor of this project, under the expedited review procedure.

Name of supervisor.....Signature..... Date.....

Office use only

Date form received:

Date decision returned to applicant:

Passed to reviewers: 1. Name.....
Date.....

(formal review only) 2. Name.....
Date.....

Ethical Issues Checklist

The purpose of this Checklist is to facilitate the review process and to identify any ethical issues that may concern the Committee. It is meant to be an aid to both the researcher and the Committee. Listed below are areas which require some justification and attention on your part in specifying your study protocol. Please answer each question honestly, giving full details where required. Answering “YES” to any of the questions will not necessarily lead to a negative response to your application but it will draw issues to your attention and give the reviewers the opportunity to ensure appropriate steps are being taken. In expedited review, supervisors should ensure that for any questions where the answer “YES” has been given, appropriate measures have been taken to maintain ethical compliance.

Applicant's full name Denis Kolozali

You must complete ALL of this section before submitting your application

1 Who is the population to be studied?

Undergraduate architecture students and architecture tutors in Cyprus.

University of Nicosia

Start:4/08/2022

End:18/08/2022

Questionnaires; Student number Min:5, Max:9 & Tutor number Min:1 Max:2

Experiments + Post-Experiment Questionnaire ; Student number Min:2, Max:3 & Tutor number Min:1 Max:2

University of Kyrenia

Start:4/08/2022

End:18/08/2022

Questionnaires; Student number Min:8, Max:12 & Tutor number Min:1 Max:2

Experiments + Post-Experiment Questionnaire ; Student number Min:8, Max:12 & Tutor number Min:1 Max:2

Near East University

Start:4/08/2022

End:18/08/2022

Questionnaires; Student number Min:5, Max:10 & Tutor number Min:1 Max:2

Experiments + Post-Experiment Questionnaire ; Student number Min:5, Max:10 & Tutor number Min:1 Max:2

Students and tutors participating will be handed out printed out questionnaires. Participants will be notified that they may fill out the questionnaire after reading and ticking the boxes on the consent pages.

- 2 Please give details of how the participants will be identified, approached and recruited.
(Include any relationship between the investigator and participants e.g. instructor-student).

Upon receiving approval from universities in Cyprus a questionnaire will be handed out to architecture tutors and undergrad students studying architecture.

Participants will be invited through an email, which will include detailed information on the study.

The questionnaire will ask students and tutors if they are willing to participate in a case study consisting of series of experiments and interviews regarding new methods and technology to teach architecture.

Volunteers will then be invited to participate in the case study.

In the case study students and tutors will be asked to complete series of tasks after going through induction prior to each session. A total of systematically progressing 4 sessions involving unique tasks and scenarios will occur each followed by a recorded interview aimed at capturing their experience.

The participant and supervisors, to reach out to prospective participants, via academic and professional networks. Participants will not be paid for participation and the survey will collect no information to reach the participant in any way.

3 Will the population studied include any vulnerable members of the public? **YES** **NO**
☐ ☒
Note: for the purpose of ethics approval this includes participants who are under 18, people who are disabled or in poor health, and also those who are non-English speakers and may not be able to understand the consent forms. (If YES, please give further details)

4 Will it be possible to associate specific information in your records with specific participants on the basis of name, position or other identifying information contained in your records? **YES** **NO**
☐ ☒

5 What steps have you taken to ensure confidentiality of personal information and anonymity of data both during the study and in the release of its findings?

This research will be following the Data Protection Act 1998 (UK) and GDPR.

No personal or demographic data is being collected in this study.

Participants will not be asked to provide email or postal address.

Participants will be requested to read and tick the contents of a consent form to give permission to the researcher to use the data collected in the study. The consent form does not collect name or email information but acts as a pre-requisite to participation in the survey.

Using tabular aggregate reporting technique, results of data will be displayed as statistics, such that no data relating to or identifying any individual is shown.

6 Describe what data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Screen Capture Recordings:

The survey includes screen video recordings.

Participants are informed in the information sheet that they must not include any identifiable information in the screen to recordings.

The interviews will be filtered for any anomalies where the participant has not complied with the request.

All subsequent records of those entries, where participant has identifiable or otherwise irrelevant information, permanently deleted from all records.

All recorded interviews will be compiled as a database.

Data collected in these recordings will then be used to run an anonymous statistical analysis and, eventually, for publication in academic journals and international conferences.

The screen recordings will be used to evaluate feasibility and implementation of method for the next phase of research

Student projects will be included as part of the study, however knowledge of ownership of projects will be limited only to the researcher.

In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed. All Electronic records will be uploaded and stored on the University's password protected Office 365 service.

Questionnaire:

The answers and results of questionnaires that will be done on paper upon arrival of students to workshops, prior to the experiment.

Questionnaire does not contain questions that can result in participants including any identifiable information

All results will be compiled as a database.

Data collected in this survey will then be used to run an anonymous statistical analysis and, eventually, for publication in academic journals and international conferences.

In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed. All Electronic records will be uploaded and stored on the researcher's password protected hard drive.

Deletion of Collected Data

After results are compiled and digitalised, researcher and his supervisor, with password protected access, have the ability to delete collected data as well as the entire survey at any time. At the end of the survey duration.

- In accordance with the Data Protection Act, paper records of will be scanned, digitally stored and afterwards printed originals destroyed. Digital data regarding recorded interviews should be stored only on a password-protected computer and/or on a secure server.
- At the end of a student project, student is responsible for ensuring that all data from the study is passed on to their academic supervisor/s. The supervisors/s will then have responsibility for the storage of that data.

- 7 Will persons participating in the study be subjected to physical or psychological discomfort, pain or aversive stimuli which is more than expected from everyday life? (If YES, please give further details) **YES** **NO**
- ☒ ☐

Since Head Mounted Display (HMD) will be used by participants in the experiment there is a chance of nausea or discomfort in eyes that can't be avoided. However, to prevent or at least minimize the effect, the participants will be informed that they are free to leave the experiment at any time. The contents of the experiments poses no psychological risk and researcher will take necessary precaution to avoid collisions with the environment while participants use VR through tutorial sessions and ensuring safe environment in accordance with university health and safety guidelines. Furthermore, the researcher will ensure that proper measures are taken against motion sickness and Covid-19. These measures are informing participants about the effects and instructions on what to do in the event of feeling motion sick. Moreover, equipment will be sterilised after each individual use to avoid risk of Covid-19 infection,

- 8 Will participants engage in strenuous or unaccustomed physical activity? (If YES, please give further details) **YES** **NO**
- ☐ ☒

- 9 Will the investigation use procedures designed to induce participants to act contrary to their wishes? (If YES, please give further details) **YES** **NO**
- ☐ ☒

.....

- 10** Will the investigation use procedures designed to induce embarrassment, humiliation, lowered self esteem, guilt, conflict, anger, discouragement or other emotional reactions? (If YES, please give further details) **YES** **NO**
☐ ☐
-
- 11** Will participants be induced to disclose information of an intimate or otherwise sensitive nature? (If YES, please give further details) **YES** **NO**
☐ ☐
-
- 12** Will participants be deceived or actively misled in any manner? (If YES, please give further details) **YES** **NO**
☐ ☐
-
- 13** Will information be withheld from participants that they might reasonably expect to receive? (If YES, please give further details) **YES** **NO**
☐ ☐
-
- 14** Will the research involve potentially sensitive topics? (If YES, please give further details) **YES** **NO**
☐ ☐
-
- 15** Will data be collected which requires potentially invasive procedures (eg attaching electrodes to the skin) and/or other health-related information to be identified (eg heart rate). If yes please give details **YES** **NO**
☐ ☐
-

If you require space for additional information, please add it here and identify the question to which it refers:

Checklist of information to include with your application:

Please tick the boxes below to confirm that you have included the following information with your submission. Failure to include the required information may result in your ethics application and approval for start of your research to be delayed.

A brief description of the study design:

number and type of participants

number and duration of activities participants will be involved in

equipment and procedures to be applied

information about how participants will be recruited

whether participants will be paid (state how this will be done)

plans to ensure participant confidentiality and anonymity

plans for storage and handling of data

information about what will happen to the data after the study

information about how any data and images may be used

state whether it will be possible to identify any individuals.

Copies of any information sheets to be given to participants (include recruitment information (e.g. adverts, posters, letters, etc)

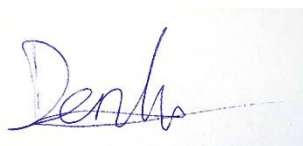
☐

A copy of the participant consent form

Copies of data collection sheets, questionnaires, etc

I confirm that all of the above is included in the application:

As the applicant I confirm that I have read and understand the Ethical requirements for my study and have read and complied with the University of Nottingham Code of Research Conduct and Research Ethics.



Signature of applicant

Date 24-07- 2022...

As supervisor, I confirm that I have checked the details of this application.

A handwritten signature in black ink, appearing to read 'J. Luthers', written in a cursive style.

Signature of supervisor

Date 21/7/22

NB The signature of the supervisor on this part of the application DOES NOT indicate supervisor approval for expedited review. If supervisor approval is granted then the front page of the application MUST be signed for approval to be confirmed.

Ethics Committee Reviewer Decision

This form must be completed by each reviewer. Each application will be reviewed by two members of the ethics committee. Reviews may be completed electronically and sent to the Faculty ethics administrator (Donna Astill-Shipman) from a University of Nottingham email address, or may be completed in paper form and delivered to the APM Hub

Applicant full name

.....

Reviewed by:

Name

.....

Signature (paper based only)

.....

Date

☐

Approval awarded - no changes required

☐

Approval awarded - subject to required changes (see comments below)

☐

Approval pending - further information & resubmission required (see comments)

☐

Approval declined – reasons given below

Comments:

.....

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Please note:

The approval only covers the participants and trials specified on the form and further approval must be requested for any repetition or extension to the investigation.

The approval covers the ethical requirements for the techniques and procedures described in the protocol but does not replace a safety or risk assessment.

Approval is not intended to convey any judgement on the quality of the research, experimental design or techniques.

Normally, all queries raised by reviewers should be addressed. In the case of conflicting or incomplete views, the ethics committee chair will review the comments and relay these to the applicant via email. All email correspondence related to the application must be copied to the Faculty research ethics administrator.

Any problems which arise during the course of the investigation must be reported to the Faculty Research Ethics Committee

Study Design

Project Title: A study of the usefulness of VR in architectural education across three universities

Participants

The requirement for the present study is 20 participants. Participants will have to meet the requirements of the study which are as follows:

Participants must be over the age of 18 and will be screened for the following:

To ensure that they are not at increased risk of experiencing simulator sickness, or would have a risk of increased harm if they do experience simulator sickness, participants must not be pregnant or susceptible to:

Migraines

Motion sickness

Epilepsy

Vertigo or dizziness

Have a pacemaker

Participant Activities

Information sheet & consent

Simulator Sickness Questionnaire (SSQ)

Participant demographic questionnaire (education, gender, VR experience)

The purpose of the study will be verbally described, and the VR system and use of controls will be demonstrated. Participants try the headset and controls, and the investigator checks for comfort and indications of simulator sickness before continuing.

Rapid SSQ assessment

Practice trial – Participants will take part in two practice trials. During the first practice task participants will be given audio instructions for using Gravity Sketch that they are required to follow. The second practice task will not have no instructions and participants have five minutes of creative freedom.

Rapid SSQ assessment

Participants are instructed that they will undergo a design discussion session in the VE and act as if they would in a design studio tutorial.

Once the participants have finished their design discussion the activity ends and they complete the short subjective questionnaire and rapid SSQ before they leave.

Participant completes final SSQ, reads debrief and fills out post-debrief agreement.

Equipment and Procedures

Oculus Quest 2 Head-Mounted VR display (HMD)

Oculus Quest 2 controller

Laptop or Desktop

Participant Recruitment

Participants will be recruited on a voluntary basis by each universities facilitator/representative using online tools such as email mailing lists. All participants must ensure they meet the study requirements before signing up.

Participant Confidentiality

All participant information such as consent, education, gender, and VR experience will be stored in paper form in a lockable cabinet. When transferred to digital format, the data will be fully anonymised. The researchers and principle investigator will be the only individuals who have access to the raw data.

Data Post-study

The data will be stored by the principle investigator for 7 years after it is used in any publications. Following a period of 7 years, physical and digital data will be destroyed.

Use of Data and Images

Screenshots of the virtual environment will be taken but will not identify the identity of participants. Anonymous data may be published in academic journals and presented at conferences but will not be associated with any participants.

Participant Identification

It will not be possible to identify participants from the data stored (education, gender, VR experience and post-task questionnaire).



Please read the following questions carefully and place a tick in the corresponding box

	Yes	No
To ensure you are not at increased risk of experiencing simulator sickness, or are susceptible to increased risk of harm if you experience simulator sickness, are you: Pregnant Or do you suffer from: Migraines Motion sickness Epilepsy Vertigo or dizziness Have a Pacemaker		
To ensure suitability to participate in the study, do you have: Normal vision, or corrected-to-normal with contact lenses		

Yes No

I have read and fully understand the participant brief provided before taking part

I am aware of my right to withdraw (data and physically) without penalty at any time during and up to one month after the study

I am aware that my data are anonymous and confidential

I have been notified that any data collected are only to be used for research purposes and not given to other organisations but may be published in academic journals or presented at conference

I give my consent to participate in this study on a voluntary basis

Date: _____

Researcher Name: _____

Researcher Signature: _____

Participant Brief

Thank you for volunteering to take part in this study. Please read and understand this brief before signing the provided consent form. This study aims to examine the feasibility of using VR HMDs in design studio which will be later used in a larger scale study. During the activities **it is imperative that you behave as you would in a regular design studio tutorial**. Student role participants will be given the chance to prepare and upload your desired 3D projects to the Virtual Environment. Tutor role participants will review, interact and discuss the student project in VE, collaboratively with the student in real time. As in regular design tutorial the tutor will determine the amount of time the discussion will take place within the VE.

Before starting the experiment, you will complete two stage tutorial in order to familiarise yourself with the controls and the task. During the first stage you will be given visual and audio instructions of how to use the VR gear and software to be used in the activity. The second stage will not have instructions and provide creative freedom to participants. Please complete the task in the same, safe manner. After completing the practice trials, you will be asked to fill out a rapid Simulator Sickness Questionnaire (SSQ).

Following the practice session, you will begin your tutorial session. Please adhere to the same instructions for these session. During this stage, you will be tasked with carrying out a design discussion in VE. Following each trial you will be asked to complete a rapid SSQ and a short questionnaire. The study will last approximately 30 minutes for each tutorial session.

Use of study data

During this session we will record the following data:

Screenshots of the virtual environment which will not identify you

Demographic data such as your gender and education

A screen recording of the VE session

Written notes detailing any feedback you give about the virtual reality system, and any issues you encounter while using it

Your name is not associated with the data we hold.

All study data will be securely stored for seven years following completion of the project and will then be destroyed, in accordance with the Data Protection Act. The data we hold will be anonymous, and it will not be possible to associate the results of this session with your identity. Data will be analysed for use in the project and may be disseminated through academic journals and presented at conferences.

In accordance with open access requirements, data from these studies may be made publicly available. However, the data will be anonymous. Similarly, metadata describing the research data held will be made freely available on the internet.

This study has been approved by the University of Nottingham Faculty of Engineering ethics committee. If you have any questions, please ask the session facilitator or contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk).

Simulator Sickness Questionnaire (SSQ)

Please tick how much each symptom is affecting you at this moment in time

	None	Slight	Moderate	Severe
General discomfort				
Fatigue				
Headache				
Eyestrain				
Difficulty focusing				
Increased salivation				
Sweating				
Nausea				
Difficulty concentrating				
Fullness of head				
Blurred vision				
Dizziness (eyes open)				
Dizziness (eyes closed)				
Vertigo				
Stomach awareness				
Burping				

Appendix M Ethics Approval for AR Experiment

Faculty of Engineering

Process for approval of research study involving human participants

Introduction

This document describes the process to be followed when planning and obtaining approval for studies involving human participants within the Faculty of Engineering. This process is based on one previously run within the School/Dept M3. The process is administered by the Faculty Research Ethics Committee, and managed by the Chair of the Ethics Committee, Dr. Robert Houghton, and Faculty Research Ethics Officer, Prof. Sarah Sharples. All queries regarding the process should be initially sent to the Faculty Ethics Administrator, Donna Astill-Shipman.

What is Ethics Approval?

When conducting any study or observation or collecting data about individuals, it is essential that full consideration is given to ethical issues and that steps are taken to ensure participant well-being throughout the study.

Participants involved in research studies have a right to:

- Know the goals of the study and who is funding the work
- Make an informed decision about whether or not they wish to participate
- Leave the study at any time if they do not wish to continue
- Know what will happen to them during the study and how long it will take
- Know if they may experience any discomfort
- Know what will happen to the findings
- Privacy of personal information
- Be treated courteously

The University of Nottingham and Faculty of Engineering have an ethics procedure that requires all staff and students to submit an application for ethical approval before conducting any research study involving human participants. Members of the Ethics Committee read through study proposals to check that the researcher has demonstrated that they have given full consideration to ethical issues and that they have provided participants with appropriate and sufficient information.

Who needs Ethics Approval?

ANY member of staff or registered student of the University of Nottingham involved in conducting any study or observation or collecting data about individuals **MUST** adhere to the University Code of Research Conduct and Research Ethics. Those affiliated with the Faculty of Engineering **MUST ALSO** comply with the Faculty ethical approval process before commencing their study.

Ethics application procedure

The attached document outlines the ethics approval process within the Faculty of Engineering. For all applications required to undergo formal review, applications must be submitted to the **Ethics Administrator**, [email: ez-eng-ethics]. The application will then be reviewed by the ethics committee. We aim to return a decision to applicants within two weeks but the procedure may be delayed if the ethics committee require further information. It is the applicant's responsibility to make sure that applications are submitted in good time. THE STUDY MAY **NOT** START UNTIL ETHICAL APPROVAL HAS BEEN AWARDED

Information you should give to ALL participants

The following list describes the information that should be given to all participants. Normally this should be given in a participant information sheet at the beginning of the study, and participants should be required to confirm that they have understood the nature of the study, and that they are happy to participate.

The following information should be included:

Details of who will be conducting the study.

Details about who is sponsoring the study and what the terms of the sponsorship are (i.e. who will 'own' the data and how the data will be used).

Details about the nature, purpose and duration of the study. (Participants whose first language is NOT English may need further explanation of what is involved as their understanding of some of the terminology may be limited).

What kinds of procedures will be used and what participant will be asked to do.

Details about any hazards, inconveniences and risks associated with the study.

What procedures will be followed if a participant is injured. (only needed if risk of injury has been identified)

What benefits (payments, expenses etc) are attached to the study.

What they need to do in order to receive the payments described above.

What procedures will be employed to maintain confidentiality and anonymity (e.g. removing personal details from data/reports, keeping data in locked files)

What will happen to the data (how it will be used, how it will be stored, in what form it will be disseminated and if it is likely to be used for further analysis).

How you will use photographs or video records (data analysis, illustration purposes, displayed to sponsors/ non-public academic audiences, printed in public domain documents etc).

Details about who to contact if questions or problems arise.

ALL participants must be told that any involvement in the study is voluntary and they are free to withdraw at any time. You should also explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

Faculty of Engineering

Application for approval of research study involving human participants

ALL applicants must provide the following information

The applicant must be the person who will conduct the investigations; each application must be made by one applicant:

usually the student in the case of taught or research courses,

usually the researcher (the member of university research or academic staff) who will conduct the study in the case of funded research projects,

usually the principal investigator in the case of applications for ethics approval in advance of submission of a research proposal

If the applicant is an Undergraduate or Postgraduate taught or research student please complete the information below. The application must be approved by a Supervisor.

Name of student:	Denis Kolozali	Student No:	4299912
Course of study:	PhD Architecture	Email address:	Denis.Kolozali@nottingham.ac.uk
Supervisor:	Dr. Peter Rutherford	PGR ☒	
	Dr. Glynn Lawson		
		MSc ☐	

If the applicant is a member of university research or academic staff, please complete the information below: For research staff, the application must be approved by the Principal Investigator

Name:		Principal Investigator	
		(Budget Holder)	
Email address:		PI Signature:	

Title of investigation: Visual Scene Preference

Planned date for study to begin **16-April-2023**.....Duration of Study **2 weeks**

Please state whether this application is:

New ☒ Revised ☐ A renewal ☐ For a continuation study ☐

Selection of review process

Please indicate whether the application is required to go forward to the ethics committee for formal review, or, in the case of projects completed by ***taught undergraduate and postgraduate students only***, whether the application can be approved by the supervisor under the expedited review process*.

☐ Formal review, application will be
by supervisor*

submitted to ethics committee
is a

☐ Expedited review, application is approved

* ☐ option can only be selected if the Supervisor

is a member of the Faculty Ethics committee

Approval by supervisor: expedited review

I approve the application as supervisor of this project, under the expedited review procedure.

Name of supervisor.....Signature..... Date.....

Office use only

Date form received:

Date decision returned to applicant:

Passed to reviewers: 1. Name.....
Date.....

(formal review only) 2. Name.....
Date.....

Ethical Issues Checklist

The purpose of this Checklist is to facilitate the review process and to identify any ethical issues that may concern the Committee. It is meant to be an aid to both the researcher and the Committee. Listed below are areas which require some justification and attention on your part in specifying your study protocol. Please answer each question honestly, giving full details where required. Answering “YES” to any of the questions will not necessarily lead to a negative response to your application but it will draw issues to your attention and give the reviewers the opportunity to ensure appropriate steps are being taken. In expedited review, supervisors should ensure that for any questions where the answer “YES” has been given, appropriate measures have been taken to maintain ethical compliance.

Applicant’s full name Denis Kolozali

You must complete ALL of this section before submitting your application

1 Who is the population to be studied?

Undergraduate architecture students and architecture tutors in Cyprus.

Near East University

Start:16/04/2023

End:28/04/2023

Questionnaires; Student number Min:5, Max:9 & Tutor number Min:1 Max:2

Experiments + Post-Experiment Questionnaire ; Student number Min:5, Max:9 & Tutor number Min:1 Max:2

University of Kyrenia

Start:16/04/2023

End:28/04/2023

Questionnaires; Student number Min:8, Max:12 & Tutor number Min:1 Max:2

Experiments + Post-Experiment Questionnaire ; Student number Min:8, Max:12 & Tutor number Min:1 Max:2

Students and tutors participating will be handed out printed out questionnaires. Participants will be notified that they may fill out the questionnaire after reading and ticking the boxes on the consent pages.

- 2** Please give details of how the participants will be identified, approached and recruited.
(Include any relationship between the investigator and participants e.g. instructor-student).

Upon receiving approval from universities in Cyprus a questionnaire will be handed out to architecture tutors and undergrad students studying architecture.

Participants will be invited through an email, which will include detailed information on the study.

The questionnaire will ask students and tutors if they are willing to participate in a case study consisting of series of experiments and interviews regarding new methods and technology to teach architecture.

Volunteers will then be invited to participate in the case study.

In the case study students and tutors will be asked to complete series of tasks after going through induction prior to each session. A total of systematically progressing 4 sessions involving unique tasks and scenarios will occur each followed by a recorded interview aimed at capturing their experience.

The participant and supervisors, to reach out to prospective participants, via academic and professional networks. Participants will not be paid for participation and the survey will collect no information to reach the participant in any way.

- 3** Will the population studied include any vulnerable members of the public? **YES** **NO**
☐ ☐
Note: for the purpose of ethics approval this includes participants who are under 18, people who are disabled or in poor health, and also those who are non-English speakers and may not be able to understand the consent forms. (If YES, please give further details)
- 4** Will it be possible to associate specific information in your records with specific participants on the basis of name, position or other identifying information contained in your records? **YES** **NO**
☐ ☐

- 5** What steps have you taken to ensure confidentiality of personal information and anonymity of data both during the study and in the release of its findings?

This research will be following the Data Protection Act 1998 (UK) and GDPR.

No personal or demographic data is being collected in this study.

Participants will not be asked to provide email or postal address.

Participants will be requested to read and tick the contents of a consent form to give permission to the researcher to use the data collected in the study. The consent form does not collect name or email information but acts as a pre-requisite to participation in the survey.

Using tabular aggregate reporting technique, results of data will be displayed as statistics, such that no data relating to or identifying any individual is shown.

- 6** Describe what data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Screen Capture Recordings:

The survey includes screen video recordings.

Participants are informed in the information sheet that they must not include any identifiable information in the screen to recordings.

The interviews will be filtered for any anomalies where the participant has not complied with the request.

All subsequent records of those entries, where participant has identifiable or otherwise irrelevant information, permanently deleted from all records.

All recorded interviews will be compiled as a database.

Data collected in these recordings will then be used to run an anonymous statistical analysis and, eventually, for publication in academic journals and international conferences.

The screen recordings will be used to evaluate feasibility and implementation of method for the next phase of research

Student projects will be included as part of the study, however knowledge of ownership of projects will be limited only to the researcher.

In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely on the University of Nottingham OneDrive system for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed. All Electronic records will be uploaded and stored on the University's password protected Office 365 service.

Questionnaire:

The answers and results of questionnaires that will be done on paper upon arrival of students to workshops, prior to the experiment.

Questionnaire does not contain questions that can result in participants including any identifiable information

All results will be compiled as a database.

Data collected in this survey will then be used to run an anonymous statistical analysis and, eventually, for publication in academic journals and international conferences.

In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed. All Electronic records will be uploaded and stored on the researcher's password protected office365 account.

- In accordance with the Data Protection Act, paper records of will be scanned, digitally stored and afterwards printed originals destroyed. Digital data regarding recorded interviews will be stored on the University of Nottingham OneDrive account..

-

- 7 Will persons participating in the study be subjected to physical or psychological discomfort, pain or aversive stimuli which is more than expected from everyday life? (If YES, please give further details) YES NO
☐ ☐
- 8 Will participants engage in strenuous or unaccustomed physical activity? (If YES, please give further details) YES NO
☐ ☐
- 9 Will the investigation use procedures designed to induce participants to act contrary to their wishes? (If YES, please give further details) YES NO
☐ ☐
.....
- 10 Will the investigation use procedures designed to induce embarrassment, humiliation, lowered self esteem, guilt, conflict, anger, discouragement or other emotional reactions? (If YES, please give further details) YES NO
☐ ☐
.....
- 11 Will participants be induced to disclose information of an intimate or otherwise sensitive nature? (If YES, please give further details) YES NO
☐ ☐
.....
- 12 Will participants be deceived or actively misled in any manner? (If YES, please give further details) YES NO
☐ ☐
.....
- 13 Will information be withheld from participants that they might reasonably expect to receive? (If YES, please give further details) YES NO
☐ ☐

.....

14	Will the research involve potentially sensitive topics? (If YES, please give further details)	YES ☐	NO ☐

.....

15	Will data be collected which requires potentially invasive procedures (eg attaching electrodes to the skin) and/or other health-related information to be identified (eg heart rate). If yes please give details	YES ☐	NO ☐

.....

If you require space for additional information, please add it here and identify the question to which it refers:

Checklist of information to include with your application:

Please tick the boxes below to confirm that you have included the following information with your submission. Failure to include the required information may result in your ethics application and approval for start of your research to be delayed.

A brief description of the study design:

number and type of participants

number and duration of activities participants will be involved in

equipment and procedures to be applied

information about how participants will be recruited

whether participants will be paid (state how this will be done)

plans to ensure participant confidentiality and anonymity

plans for storage and handling of data

information about what will happen to the data after the study

information about how any data and images may be used

state whether it will be possible to identify any individuals.

Copies of any information sheets to be given to participants (include recruitment information (e.g. adverts, posters, letters, etc)

☐

A copy of the participant consent form

Copies of data collection sheets, questionnaires, etc

I confirm that all of the above is included in the application:

As the applicant I confirm that I have read and understand the Ethical requirements for my study and have read and complied with the University of Nottingham Code of Research Conduct and Research Ethics.

Signature of applicant

Date 24-07- 2022...

As supervisor, I confirm that I have checked the details of this application.

Signature of supervisor..... Date:

NB The signature of the supervisor on this part of the application DOES NOT indicate supervisor approval for expedited review. If supervisor approval is granted then the front page of the application MUST be signed for approval to be confirmed.

Ethics Committee Reviewer Decision

This form must be completed by each reviewer. Each application will be reviewed by two members of the ethics committee. Reviews may be completed electronically and sent to the Faculty ethics administrator (Donna Astill-Shipman) from a University of Nottingham email address, or may be completed in paper form and delivered to the APM Hub

Applicant full name

.....

Reviewed by:

Name

.....

Signature (paper based only)

.....

Date

☐

Approval awarded - no changes required

☐

Approval awarded - subject to required changes (see comments below)

☐

Approval pending - further information & resubmission required (see comments)

☐

Approval declined – reasons given below

Comments:

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Please note:

The approval only covers the participants and trials specified on the form and further approval must be requested for any repetition or extension to the investigation.

The approval covers the ethical requirements for the techniques and procedures described in the protocol but does not replace a safety or risk assessment.

Approval is not intended to convey any judgement on the quality of the research, experimental design or techniques.

Normally, all queries raised by reviewers should be addressed. In the case of conflicting or incomplete views, the ethics committee chair will review the comments and relay these to the applicant via email. All email correspondence related to the application must be copied to the Faculty research ethics administrator.

Any problems which arise during the course of the investigation must be reported to the Faculty Research Ethics Committee

Study Design

Project Title: A study of the usefulness of AR in architectural education across two universities

Participants

The requirement for the present study is 20 participants. Participants will have to meet the requirements of the study which are as follows:

Participants must be over the age of 18 and will be screened for the following:

To ensure that they are not at increased risk of experiencing discomfort, or would have a risk of increased harm if they do experience sickness, participants must not be susceptible to:

Migraines

Epilepsy

Participant Activities

Information sheet & consent

Participant demographic questionnaire (education, gender, AR experience)

The purpose of the study will be verbally described, and the AR system and use of controls will be demonstrated. Participants try the iPad and stylus.

Practice trial – Participants will take part in two practice trials. During the first practice task participants will be given audio instructions for using Gravity Sketch (AR) that they are required to follow. The second practice task will not have no instructions and participants have five minutes of creative freedom.

Participants are instructed that they will undergo a design discussion session in the VE and act as if they would in a design studio tutorial.

Once the participants have finished their design discussion the activity ends and they complete the short subjective questionnaire before they leave.

Participant completes the activity by reading the debrief and fills out post-debrief agreement.

Equipment and Procedures

iPad Pro

Stylus

Laptop or Desktop

Participant Recruitment

Participants will be recruited on a voluntary basis by each universities facilitator/representative using online tools such as email mailing lists. All participants must ensure they meet the study requirements before signing up.

Participant Confidentiality

All participant information such as consent, education, gender, and VR experience will be stored in paper form in a lockable cabinet. When transferred to digital format, the data will be fully anonymised. The researchers and principle investigator will be the only individuals who have access to the raw data.

Data Post-study

The data will be stored by the principle investigator for 7 years after it is used in any publications. Following a period of 7 years, physical and digital data will be destroyed.

Use of Data and Images

Screenshots of the virtual environment will be taken but will not identify the identity of participants. Anonymous data may be published in academic journals and presented at conferences but will not be associated with any participants.

Participant Identification

It will not be possible to identify participants from the data stored (education, gender, VR experience and post-task questionnaire).

Architectural Education in AE Study Consent Form

Please read the following questions carefully and place a tick in the corresponding box

Yes No

I have read and fully understand the participant brief provided before taking part

I am aware of my right to withdraw (data and physically) without penalty at any time during and up to one month after the study

I am aware that my data are anonymous and confidential

I have been notified that any data collected are only to be used for research purposes and not given to other organisations but may be published in academic journals or presented at conference

I give my consent to participate in this study on a voluntary basis

Date: _____

Researcher Name: _____

Researcher Signature: _____

Participant Brief

Thank you for volunteering to take part in this study. Please read and understand this brief before signing the provided consent form. This study aims to examine the feasibility of using AR Displays in design studio which will be later used in a larger scale study. During the activities **it is imperative that you behave as you would in a regular design studio tutorial**. Student role participants will be given the chance to prepare and upload your desired 3D projects to the Augmented Environment. Tutor role participants will review, interact and discuss the student project in AE (Augmented Environment), collaboratively with the student in real time. As in regular design tutorials the tutor will determine the amount of time the discussion will take place within the AE.

Before starting the experiment, you will complete a two stage tutorial in order to familiarise yourself with the controls and the task. During the first stage you will be given visual and audio instructions of how to use the AR gear and software to be used in the activity. The second stage will not have instructions and provide creative freedom to participants. Please complete the task in the same, safe manner.

Following the practice session, you will begin your tutorial session. Please adhere to the same instructions for these session. During this stage, you will be tasked with carrying out a design discussion in AE. Following each trial, you will be asked to complete a short questionnaire. The study will last approximately 30 minutes for each tutorial session.

Use of study data

During this session we will record the following data:

Screenshots of the virtual environment which will not identify you

Demographic data such as your gender and education

A screen recording of the AE session

Written notes detailing any feedback you give about the virtual reality system, and any issues you encounter while using it

Your name is not associated with the data we hold.

All study data will be securely stored for seven years following completion of the project and will then be destroyed, in accordance with the Data Protection Act. The data we hold will be anonymous, and it will not be possible to associate the results of this session with your identity. Data will be analysed for use in the project and may be disseminated through academic journals and presented at conferences.

In accordance with open access requirements, data from these studies may be made publicly available. However, the data will be anonymous. Similarly, metadata describing the research data held will be made freely available on the internet.

This study has been approved by the University of Nottingham Faculty of Engineering ethics committee. If you have any questions, please ask the session facilitator or contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk).

Appendix N Ethics Approval for MR Experiment

Faculty of Engineering

Process for approval of research study involving human participants

Introduction

This document describes the process to be followed when planning and obtaining approval for studies involving human participants within the Faculty of Engineering. This process is based on one previously run within the School/Dept M3. The process is administered by the Faculty Research Ethics Committee, and managed by the Chair of the Ethics Committee, Dr. Robert Houghton, and Faculty Research Ethics Officer, Prof. Sarah Sharples. All queries regarding the process should be initially sent to the Faculty Ethics Administrator, Donna Astill-Shipman.

What is Ethics Approval?

When conducting any study or observation or collecting data about individuals, it is essential that full consideration is given to ethical issues and that steps are taken to ensure participant well-being throughout the study.

Participants involved in research studies have a right to:

- Know the goals of the study and who is funding the work
- Make an informed decision about whether or not they wish to participate
- Leave the study at any time if they do not wish to continue
- Know what will happen to them during the study and how long it will take
- Know if they may experience any discomfort
- Know what will happen to the findings
- Privacy of personal information
- Be treated courteously

The University of Nottingham and Faculty of Engineering have an ethics procedure that requires all staff and students to submit an application for ethical approval before conducting any research study involving human participants. Members of the Ethics Committee read through study proposals to check that the researcher has demonstrated that they have given full consideration to ethical issues and that they have provided participants with appropriate and sufficient information.

Who needs Ethics Approval?

ANY member of staff or registered student of the University of Nottingham involved in conducting any study or observation or collecting data about individuals **MUST** adhere to the University Code of Research Conduct and Research Ethics. Those affiliated with the Faculty of Engineering **MUST ALSO** comply with the Faculty ethical approval process before commencing their study.

Ethics application procedure

The attached document outlines the ethics approval process within the Faculty of Engineering. For all applications required to undergo formal review, applications must be submitted to the **Ethics Administrator**, [email: ez-eng-ethics]. The application will then be reviewed by the ethics committee. We aim to return a decision to applicants within two weeks but the procedure may be delayed if the ethics committee require further information. It is the applicant's responsibility to make sure that applications are submitted in good time. THE STUDY MAY **NOT** START UNTIL ETHICAL APPROVAL HAS BEEN AWARDED

Information you should give to ALL participants

The following list describes the information that should be given to all participants. Normally this should be given in a participant information sheet at the beginning of the study, and participants should be required to confirm that they have understood the nature of the study, and that they are happy to participate.

The following information should be included:

Details of who will be conducting the study.

Details about who is sponsoring the study and what the terms of the sponsorship are (i.e. who will 'own' the data and how the data will be used).

Details about the nature, purpose and duration of the study. (Participants whose first language is NOT English may need further explanation of what is involved as their understanding of some of the terminology may be limited).

What kinds of procedures will be used and what participant will be asked to do.

Details about any hazards, inconveniences and risks associated with the study.

What procedures will be followed if a participant is injured. (only needed if risk of injury has been identified)

What benefits (payments, expenses etc) are attached to the study.

What they need to do in order to receive the payments described above.

What procedures will be employed to maintain confidentiality and anonymity (e.g. removing personal details from data/reports, keeping data in locked files)

What will happen to the data (how it will be used, how it will be stored, in what form it will be disseminated and if it is likely to be used for further analysis).

How you will use photographs or video records (data analysis, illustration purposes, displayed to sponsors/ non-public academic audiences, printed in public domain documents etc).

Details about who to contact if questions or problems arise.

ALL participants must be told that any involvement in the study is voluntary and they are free to withdraw at any time. You should also explain any consequences for the participant of withdrawing from the study and indicate what will be done with the participant's data if they withdraw.

Faculty of Engineering

Application for approval of research study involving human participants

ALL applicants must provide the following information

The applicant must be the person who will conduct the investigations; each application must be made by one applicant:

usually the student in the case of taught or research courses,

usually the researcher (the member of university research or academic staff)

who will conduct the study in the case of funded research projects,

usually the principal investigator in the case of applications for ethics approval in advance of submission of a research proposal

If the applicant is an Undergraduate or Postgraduate taught or research student please complete the information below. The application must be approved by a Supervisor.

Name of student:	Denis Kolozali	Student No:	4299912
Course of study:	PhD Architecture	Email address:	Denis.Kolozali@nottingham.ac.uk
Supervisor:	Dr. Peter Rutherford Dr. Glynn Lawson Mr. Graeme Baker	PGR ☒	
		MSc ☐	

If the applicant is a member of university research or academic staff, please complete the information below: For research staff, the application must be approved by the Principal Investigator

Name:		Principal Investigator (Budget Holder)	
Email address:		PI Signature:	

Title of investigation: Visual Scene Preference

Planned date for study to begin **23-October-2023**.....Duration of Study **2 months**

Please state whether this application is:

☐ New ☐ Re-ed ☐ A renewal ☒ For a continuation study

Selection of review process

Please indicate whether the application is required to go forward to the ethics committee for formal review, or, in the case of projects completed by **taught undergraduate and postgraduate students only**, whether the application can be approved by the supervisor under the expedited review process*.

☒ Formal review, application will be submitted to ethics committee the Supervisor is a

Expedited review, application

☐ * This option can only be selected if

member of the Faculty Ethics committee

Approval by supervisor: expedited review

I approve the application as supervisor of this project, under the expedited review procedure.

Name of supervisor.....Signature.....
Date.....

Office use only

Date form received:
applicant:

Date decision returned to

Passed to reviewers:
Date.....

1. Name.....

(formal review only)

2. Name.....

Date.....

Ethical Issues Checklist

The purpose of this Checklist is to facilitate the review process and to identify any ethical issues that may concern the Committee. It is meant to be an aid to both the researcher and the Committee. Listed below are areas which require some justification and attention on your part in specifying your study protocol. Please answer each question honestly, giving full details where required. Answering "YES" to any of the questions will not necessarily lead to a negative response to your application but it will draw issues to your attention and give the reviewers the opportunity to ensure appropriate steps are being taken. In expedited review, supervisors should ensure that for any questions where the answer "YES" has been given, appropriate measures have been taken to maintain ethical compliance.

Applicant's full name Denis Kolozali

You must complete ALL of this section before submitting your application

1 Who is the population to be studied?

Undergraduate architecture students and architecture tutors in Cyprus.

Final International University

Start: 23/10/2023

End: 20/12/2023

Questionnaires; Student number Min:30 & Tutor number Min:7
Experiments + Post-Experiment Questionnaire ; Student number Min:30 & Tutor number Min:7

Near East University

Start: 23/10/2023

End: 20/12/2023

Questionnaires; Student number Min:20 & Tutor number Min:5
Experiments + Post-Experiment Questionnaire ; Student number Min:20 & Tutor number Min:5

University of Kyrenia

Start: 23/10/2023

End: 20/12/2023

Questionnaires; Student number Min:15 & Tutor number Min:4
Experiments + Post-Experiment Questionnaire ; Student number Min:15 & Tutor number Min:4

Students and tutors participating will be handed out printed out questionnaires. Participants will be notified that they may fill out the questionnaire after reading and ticking the boxes on the consent pages.

- 2** Please give details of how the participants will be identified, approached and recruited. (Include any relationship between the investigator and participants e.g. instructor-student).

Upon receiving approval from universities in Cyprus a questionnaire will be handed out to architecture tutors and undergrad students studying architecture.

The questionnaire will ask students and tutors if they are willing to participate in a case study consisting of series of experiments and interviews regarding new methods and technology to teach architecture.

Participants will be invited through an email, which will include detailed information on the study.

Volunteers will then be invited to participate in the case study.

- 3** Will the population studied include any vulnerable members of the public? **YES** **NO**
Note: for the purpose of ethics approval this includes participants who are under 18, people who are disabled or in poor health, and also those who are non-English speakers and may not be able to understand the consent forms. (If YES, please give further details) ☐ ☒

- 4** Will it be possible to associate specific information in your records with specific participants on the basis of name, position or other identifying information contained in your records? **YES** **NO**
☐ ☒

- 5** What steps have you taken to ensure confidentiality of personal information and anonymity of data both during the study and in the release of its findings?

No personally identifiable information will be gathered and therefore individual identities will not be able to be attributed in the study and any further write up.

- 6** Describe what data will be stored, where, for what period of time, the measures that will be put in place to ensure security of the data, who will have access to the data, and the method and timing of disposal of the data.

Screen Capture Recordings:

The survey includes screen recordings of the sessions, no identifiable video or audio recordings of participants will be captured.

Participants are informed in the information sheet that they must not include any identifiable information in the screen to recordings.

The sessions will be filtered for any anomalies where the participant has not complied with the request.

All subsequent records of those entries, where participant has identifiable or otherwise irrelevant information, permanently deleted from all records.

All recorded sessions will be compiled as a database.

Data collected in these recordings will then be used to run an anonymous statistical analysis and, eventually, for publication in academic journals and international conferences.

The screen recordings will be used to evaluate feasibility and implementation of method for the next phase of research

In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely on the University of Nottingham OneDrive system for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed. All Electronic records will be uploaded and stored on the University's password protected Office 365 service.

Questionnaire:

The answers and results of questionnaires that will be done on paper upon arrival of students to workshops, prior to the experiment.

Paper records will be scanned, digitally stored and afterwards printed originals destroyed.

Questionnaires do not contain questions that can result in participants including any identifiable information

All results will be compiled as a database.

Data collected in this survey will then be used to run an anonymous statistical analysis and, eventually, for publication in academic journals and international conferences.

In accordance with the Data Protection Act and the rule of the University of Nottingham, the data will be kept securely for seven years following publication of results. After this time, electronic files will be deleted and any hard copies will be destroyed. All Electronic records will be uploaded and stored on the researcher's password protected office365 account.

- 7** Will persons participating in the study be subjected to physical or psychological discomfort, pain or aversive stimuli which is more than expected from everyday life? (If YES, please give further details) **YES** **NO**
☒ ☐

Since a Head Mounted Display (HMD) will be used by participants in the experiment there is a chance of nausea or visual discomfort that can't be avoided. However, to prevent or at least minimize the effect, the participants will be informed that they are free to leave the experiment at any time. The contents of the experiments pose no psychological risk and researcher will take necessary precaution to avoid collisions with the environment while participants use VR through tutorial sessions and ensuring safe environment in accordance with university health and safety guidelines. Furthermore, the researcher will ensure that proper measures are taken against motion sickness and Covid-19. These measures are informing participants about the effects and instructions on what to do in the event of feeling motion sick. Moreover, equipment will be sterilised after each individual use to avoid risk of Covid-19 infection,

- 8** Will participants engage in strenuous or unaccustomed physical activity? (If YES, please give further details) **YES** **NO**
☐ ☒

- 9** Will the investigation use procedures designed to induce participants to act contrary to their wishes? (If YES, please give further details) **YES** **NO**
☐ ☒

...

- 10** Will the investigation use procedures designed to induce embarrassment, humiliation, lowered self esteem, guilt, conflict, anger, discouragement or other emotional reactions? (If YES, please give further details) **YES** **NO**
☐ ☒

...

- 11** Will participants be induced to disclose information of an intimate or otherwise sensitive nature? (If YES, please give further details) **YES** **NO**
☐ ☒

...

- 12** Will participants be deceived or actively misled in any manner? (If YES, please give further details) **YES** **NO**
☐ ☒

...

13 Will information be withheld from participants that they might reasonably expect to receive? (If YES, please give further details) **YES** **NO**

☐☐

.....
...

14 Will the research involve potentially sensitive topics? (If YES, please give further details) **YES** **NO**

☐☐

.....
...

15 Will data be collected which requires potentially invasive procedures (eg attaching electrodes to the skin) and/or other health-related information to be identified (eg heart rate). If yes please give details **YES** **NO**

☐☐

.....
...

If you require space for additional information, please add it here and identify the question to which it refers:

Checklist of information to include with your application:

Please tick the boxes below to confirm that you have included the following information with your submission. Failure to include the required information may result in your ethics application and approval for start of your research to be delayed.

A ☐ brief description of the study design:

number and type of participants

number and duration of activities participants will be involved in

equipment and procedures to be applied

information about how participants will be recruited

whether participants will be paid (state how this will be done)

plans to ensure participant confidentiality and anonymity

plans for storage and handling of data

information about what will happen to the data after the study

information about how any data and images may be used

state whether it will be possible to identify any individuals.

Copies of any information sheets to be given to participants (include recruitment information (e.g. adverts, posters, letters, etc)

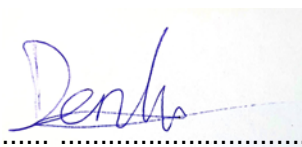
A ☐ copy of the participant consent form

Copies of data collection sheets, questionnaires, etc

I confirm that all of the above is included in the application:

As the applicant I confirm that I have read and understand the Ethical requirements for my study and have read and complied with the University of Nottingham Code of Research Conduct and Research Ethics.

Signature of applicant



Date 05-10- 2023...

As supervisor, I confirm that I have checked the details of this application.

Signature of supervisor



Date: 05/10/2023

NB The signature of the supervisor on this part of the application DOES NOT indicate supervisor approval for expedited review. If supervisor

approval is granted then the front page of the application MUST be signed for approval to be confirmed.

This form must be completed by each reviewer. Each application will be reviewed by two members of the ethics committee. Reviews may be completed electronically and sent to the Faculty ethics administrator (Donna Astill-Shipman) from a University of Nottingham email address, or may be completed in paper form and delivered to the APM Hub

.....

Name

.....

Date

Approval awarded - subject to required changes (see comments below)

☐ Approval declined – reasons given below[illegible]

Please note:

The approval only covers the participants and trials specified on the form and further approval must be requested for any repetition or extension to the investigation.

The approval covers the ethical requirements for the techniques and procedures described in the protocol but does not replace a safety or risk assessment.

Approval is not intended to convey any judgement on the quality of the research, experimental design or techniques.

Normally, all queries raised by reviewers should be addressed. In the case of conflicting or incomplete views, the ethics committee chair will review the comments and relay these to the applicant via email. All email correspondence related to the application must be copied to the Faculty research ethics administrator.

Any problems which arise during the course of the investigation must be reported to the Faculty Research Ethics Committee

Study Design

Project Title: A study of the usefulness of enhanced reality in architectural education across two universities

Participant Confidentiality

All participant information such as consent, education, gender, and VR/AR experience will be stored in paper form in a lockable cabinet. When transferred to digital format, the data will be fully anonymised. The researchers and principle investigator will be the only individuals who have access to the raw data.

Participants

The requirement for the present study is 50 participants. Participants will have to meet the requirements of the study which are as follows:

Participants must be over the age of 18 and will be screened for the following:

To ensure that they are not at increased risk of experiencing simulator sickness, or would have a risk of increased harm if they do experience simulator sickness, participants must not be pregnant or susceptible to:

Migraines

Motion sickness

Epilepsy

Vertigo or dizziness

Have a pacemaker

Participant Activities

Information sheet & consent

Simulator Sickness Questionnaire (SSQ)

Participant demographic questionnaire (education, gender, VR experience)

The purpose of the study will be verbally described, and the VR system and use of controls will be demonstrated. Participants try the headset and controls, and the investigator checks for comfort and indications of simulator sickness before continuing.

Rapid SSQ assessment (the purpose of this assessment is to periodically check on the health and well-being of the participants).

Practice trial – Participants will take part in two practice trials. During the first practice task participants will be given audio instructions for using Gravity Sketch that they are required to follow. The second practice task will not have no instructions and participants have five minutes of creative freedom.

Rapid SSQ assessment

Participants are instructed that they will undergo a design discussion session in the VE and act as if they would in a design studio tutorial.

Once the participants have finished their design discussion the activity ends and they complete the short subjective questionnaire and rapid SSQ before they leave.

Participant completes final SSQ, reads debrief and fills out post-debrief agreement.

Participant is given weekly post session questionnaire.

On the last session participants will be given post experiment questionnaire

Equipment and Procedures

Oculus Quest 2 Head-Mounted VR display (HMD)

Oculus Quest 2 controller

iPad Pro

Stylus

Laptop or Desktop

Participant Recruitment

Participants will be recruited on a voluntary basis by each universities facilitator/representative using online tools such as email mailing lists. All participants must ensure they meet the study requirements before signing up.

Data Post-study

The data will be stored by the principle investigator for 7 years after it is used in any publications. Following a period of 7 years, physical and digital data will be destroyed.

Use of Data and Images

Screenshots of the virtual environment will be taken but will not identify the identity of participants. Anonymous data may be published in academic journals and presented at conferences but will not be associated with any participants.

Participant Identification

It will not be possible to identify participants from the data stored (education, gender, VR/AR experience and post-task questionnaire).

Architectural Education in Enhanced Reality Pilot Study **Consent Form**



The University of
Nottingham

Participant Brief

Thank you for volunteering to take part in this study. Please read this brief before signing the provided consent form.

This study aims to examine the feasibility of using enhanced reality in design studio which will be later used in a larger scale study. Student role participants will be given the chance to prepare and upload your desired 3D projects to the Enhanced Environment. Tutor role participants will review, interact and discuss the student project in ER (Enhanced Reality), collaboratively with the student in real time. As in regular design tutorials the tutor will determine the amount of time the discussion will take place within the ER.

Before starting the experiment, you will complete a two stage tutorial in order to familiarise yourself with the controls and the tools. During the first stage you will be given visual and audio instructions of how to use both the VR & AR gear and software to be used in the activity. The second stage will not have instructions and provide creative freedom to participants. Please complete the task in the same, safe manner.

Following the practice session, you will begin your tutorial session at any stage you see fit for your design project. Please adhere to the same instructions for these session. During this stage, you will be tasked with carrying out a design discussion in ER. Following each trial, you will be asked to complete a short questionnaire. The study will last approximately 30 minutes for each tutorial session. Use of study data

During this session we will record the following data:

Screenshots of the virtual environment which will not identify you

Demographic data such as your gender and education

A screen recording of the ER session

Written notes detailing any feedback you give about the virtual reality system, and any issues you encounter while using it

Your name is not associated with the data we hold.

All study data will be securely stored for seven years following completion of the project and will then be destroyed, in accordance with the Data Protection Act. The data we hold will be anonymous, and it will not be possible to associate the results of this session with your identity. Data will be analysed for use in the project and may be disseminated through academic journals and presented at conferences.

In accordance with open access requirements, data from these studies may be made publicly available. However, the data will be anonymous. Similarly, metadata describing the research data held will be made freely available on the internet.

Note: participation is voluntary and unpaid.

Yes No

I have read and fully understand the participant brief provided before taking part

I am aware of my right to withdraw (data and physically) without penalty at any time during and up to one month after the study

I am aware that my data are anonymous and confidential

I have been notified that any data collected are only to be used for research purposes and not given to other organisations but may be published in academic journals or presented at conference

I give my consent to participate in this study on a voluntary basis

Date: _____

Researcher Name: _____

Researcher Signature: _____

This study has been approved by the University of Nottingham Faculty of Engineering ethics committee. If you have any questions, please ask the session facilitator or contact Denis Kolozali (Denis.Kolozali@nottingham.ac.uk).