A METAVERSE-BASED PLAYGROUND FOR ARCHITECTURAL EDUCATION, MPAD

A THESIS SUBMITTED TO

THE GRADUATE SCHOOL OF ENGINEERING AND SCIENCE

OF BILKENT UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF

MASTER OF SCIENCE

IN

ARCHITECTURE

By

BİLGE SAĞLAM

July 2024

Dedicated to my dear parents

In loving memory of my beloved grandma and my dear cat Beyaz

A METAVERSE-BASED PLAYGROUND FOR ARCHITECTURAL EDUCATION, MPAD

By Bilge Sağlam

July 2024

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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Director of the Graduate School

ABSTRACT

A METAVERSE-BASED PLAYGROUND

FOR ARCHITECTURAL EDUCATION, MPAD

Bilge Sağlam

M.S. in Architecture

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July 2024

Educational processes have faced a paradigmatic shift in integrating virtual environments and novel technologies. This rapid change in recent history has led to increase the use of diverse novel methodologies in research on design education approaches. Architectural design education, which relies on practice and physical participation, is where research should be intensified by following leading technologies and methods to ensure sustainability. In this context, immersive virtual environments, rapidly developing metaverse technologies, and the adoption of game-based educational models display potential for architectural education studies. This thesis develops and examines a metaverse-based collaborative virtual model for basic design in architectural education using a game-based learning approach. The concepts of the *metaverse* as a holistic virtual environment and *games* as creative methods form the foundation of this learning approach, an educational playground. This playground is introduced to basic design students based on the CIX building block game (1996), developed from a geometry-based system by French architect Fabien Vienne (1925-2016). CIX blocks were reconstructed in a multi-user virtual playground called MPAD (Metaverse-based Playground for Architectural Education). MPAD was experienced by 38 participants in a collaborative environment with VR headsets and the Collaborative Learning Assessment, an adaptation of the Technology Acceptance Model, was applied to the participants. The results indicate that the MPAD experience in design education yields positive results. In the future, MPAD aims to serve as an example of immersive reality technologies and collaborative design approaches.

Keywords: Architecture Education, Basic Design, Digital Game-based Learning, Metaverse, Fabien Vienne

ÖZET

MİMARLIK EĞİTİMİNE YÖNELİK

METAVERSE TABANLI OYUN ALANI, MPAD

Bilge Sağlam

Mimarlık Yüksek Lisans

Tez Danışmanı: Burcu Şenyapılı Özcan

July 2024

Sanal ortamların ve yeni teknolojilerin eğitim süreçlerine dahil edilmesiyle paradigmatik bir değişim yaşanmıştır. Yakın tarihteki bu hızlı değişim ile, tasarım eğitimi yaklaşımları üzerine yapılan araştırmalarda çeşitli yeni yöntemlerin kullanımı artmıştır. Uygulamaya ve fiziksel katılıma dayalı mimari tasarım eğitimi, sürdürülebilirliğinin sağlanması için önde gelen teknoloji ve yöntemlerin takip edilerek araştırmaların yoğunlaştırılması gereken bir alandır. Bu bağlamda, kapsayıcı sanal ortamlar, hızla gelişen metaverse teknolojileri ve oyun tabanlı eğitim modellerinin benimsenmesi mimarlık eğitimi çalışmalarının odak noktaları arasında yer alacaktır. Bu tez, mimarlıkta temel tasarım eğitimi için oyun tabanlı öğrenme yaklaşımı ile kurgulanmış metaverse tabanlı işbirlikçi bir sanal model geliştirmeyi ve incelemeyi amaçlamaktadır. Metaverse kavramı bütüncül bir sanal ortam olarak, oyun kavramı ise yaratıcı yöntemlerden biri olarak bu öğrenme yaklaşımının temellerini oluşturmaktadır. Bu oyun alanı, Fransız mimar Fabien Vienne (1925-2016) tarafından geometri temelli bir sistem olan CIX yapı bloklarına (1996) dayanmaktadır. CIX, MPAD (Metaverse-based Playground for Architectural Education) isimli çok kullanıcılı sanal oyun alanında yeniden yapılandırılmıştır. MPAD, 38 katılımcı tarafından VR başlıkları ile işbirlikçi bir ortamda deneyimlenmiştir ve katılımcılara İşbirlikçi Öğrenme Değerlendirmesi uygulanmıştır. Sonuçlar, lisans düzeyindeki mimari temel tasarım eğitiminde MPAD deneyiminin olumlu sonuçlar verdiğini göstermektedir. Gelecekte, MPAD'in kapsayıcı gerçeklik teknolojileri ve işbirlikçi tasarım yaklaşımlarına örnek teşkil etmesi hedeflenmektedir.

Anahtar Kelimeler: Mimarlık Eğitimi, Temel Tasarım, Dijital Oyun Tabanlı Öğrenme, Metaverse, Fabien Vienne

ACKNOWLEDGEMENTS

Foremost, I would like to express my deepest gratitude to my supervisor, Assoc. Prof. Dr. Burcu Şenyapılı Özcan, for her continuous guidance, inspiration, and motivation throughout this journey. This thesis would not have been possible without her belief in me and her unwavering support in helping me discover my own path and interests. I sincerely thank my thesis committee members, Prof. Dr. Yasemin Afacan, for her invaluable feedback and constructive contributions, and Assoc. Prof. Dr. Aktan Acar, for his support and valuable insights, has influenced me since my undergraduate.

My appreciation extends to Bilkent University for guidance during the MPAD workshops and TÜBİTAK 1002 project. I want to thank the faculty and my colleagues at Ostim Technical University for their support and understanding. I am also fortunate to have the friendship of the research assistant team at Ostim Technical University during this journey. I am grateful to Prof. Dr. Birsen Şahin Kütük and Prof. Dr. Zülfü Umut Özkara for their valuable suggestions about statistical methods and to the Simlab Soft technical team for their guidance in resolving multi-user experience and model issues. I also appreciate all the participants from Bilkent University and Ostim Technical University who generously dedicated their time to this research.

A special thanks to my aunt, Prof. Dr. Güler Sağlam Arı, for her continuous support and valuable motivation, especially when I struggled with statistical analysis. I am also incredibly lucky to have Aslı Altun’s friendship. She has been a constant companion throughout my thesis study. I want to thank all my friends who tested MPAD and gave feedback.

I will always be eternally grateful to my family: my mother, Nurcan Karakuş Sağlam, and my father, Prof. Dr. Serdar Sağlam. They have always given me unconditional love and faith. I can't be grateful enough to have these two wonderful people who have supported every dream I have ever had and who have always been by my side.

I would also like to express my gratitude for having two more beautiful people who have always been with me and raised me: my grandfather and my grandmother. Although my grandmother is no longer physically with us, her presence resonates with me. I still feel the warmth of her love and the strength she gave me.

I also want to thank my dear, monochrome, non-human companion, my ball-master, who will never be forgotten and will always be missed. I owe so much to the year we spent together during my master's.

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LIST OF ABBREVIATIONS

2D 2 Dimensional

3D 3 Dimensional

CAD Computer-aided Design

CADD Computer-aided Design and Drafting

CAM Computer-aided Manufacturing

CLA Collaborative Learning Assessment

DGBL Digital Game-Based Learning

ECM Expectation-Confirmation Model

GBL Game-Based Learning

HIVE Highly Interactive Virtual Environments (HIVEs)

MPAD Metaverse-based Playground for Architectural Education

MR Mixed Reality

SD Standard Deviation

TAM Technology Acceptance Model

TRA (Theory of Planned Behaviour)

VR Virtual Reality

VW Virtual World

XR Extended Reality

CHAPTER 1

INTRODUCTION

Architectural design education is one of the areas where research needs to be intensified to keep pace with digital and virtual developments to ensure its sustainability. The developments in digital and virtual technologies have been fast and comprehensive. Computer-aided working stations and new design processes were envisioned in the 1950s with the emergence and popularization of computer technology (Mitchell, 1990). Dr Patrick Hanratty is considered as the designer of the the first computer-aided manufacturing (CAM) software and accepted as the “father of CAM" with his programming tool PRONTO (1957) (Aouad et al., 2012). In the early 1960s, innovations were made in digitizing design processes, starting with Ivan Sutherland's Sketchpad (1964), which laid the foundation for computer-aided design (CAD) systems and graphical interfaces. Sutherland’s supervisor Steven Coons, and Douglas Ross lead the collective CAD project at MIT during 1959-1970, which is also considered the initial systematic experiment of the human-machine interaction focusing design 1959-1970 (Llach, 2015). The attempts for CAD systems have

continued to develop and have been utilized widely in practice since the 1970s (Mitchell, 1977). The advent of personal computers in the early 1980s facilitated the wider accessibility of CAD applications. At the same time, the advent of the Internet can be traced back to the 1980s when it emerged as a primarily academic network. It was not until the early 1990s that it began to gain broader acceptance. Frazer (1995) mentions a paradigm shift in architecture with the emergence of cyberspace in the 1960s when the term was first mentioned. This new architecture is the relationship of forms with its users and creators in cyberspace, enabling modeling in a responsive environment guided by computers and global collaboration using internet networks. The massive changes began in the 1990s in virtual worlds that appeared with 3D graphics, which allow socializing, collaboration, creating and selling objects, and presenting spaces for educational purposes (Downey, 2014).

On the other hand, Zimmerman (2014) declares that games will define the 20th century, the century of information. The interactive and game-like experiences are modular, adaptable, and participatory. Negroponte (1970) argues that games function as potent tools for learning owing to their multifaceted nature. They embody strategies that require abstraction and the artificial simulation of complex scenarios. This is exemplified by how games comprise a series of localized pursuits that collectively contribute to realizing a global goal. For instance, games are concerned with the creation of a good life or with the construction of a well-thought-out structure. Games are recreational and immersive educational experiences that cultivate skills applicable

to life and design. Players learn from their failures and successes in games, enhancing their understanding of evolving strategies in dynamic environments.

The design process can be defined as the pursuit of finding satisfying solutions to meet goals. Yet the difficulty of finding and deciding the right solution from the "universe of potentials" makes the design process unpredictable and challenging. Since ancient Greek times, architects developed design methods to effectively overcome the unpredictable nature of the design process in the pursuit of a satisfying one (Kalay, 2004). The digital turn (Carpo, 2013) has nourished new design process alternatives.

The integration of engaging gameplay into architectural design contexts can be traced back to the 1970s (Feldt, 1972; Green, 1979; Bonta, 1979). The immersive and interactive interfaces of the game systems have the potential to alter educational practices (Kapp, 2012) and affect design processes (Kalay and Jeong, 2003). Extended reality technologies have led to the integration of immersive environments within studio environments, thereby gradually transforming the tactile experiences associated with such environments (Donath and Regenbrecht, 1996). While many developments and experiences in the virtual design process are explored individually, the interactive nature of game-based learning experiments is a notable exception. The advent of virtual worlds and metaverse systems has augmented the practice and studio environments by providing alternative realities for experiments. The collaborative experiences are following the spatial augmentation that characterizes this new era.

In this context, increasing game-based education models, inclusive virtual environments, and recently rapidly developing Metaverse technologies will be among the focal subjects of studies on architectural education. In this context, the game-based education approach and the inclusive virtual universe of the metaverse are worth investigating for their potentials.

1.1 Problem Statement

Cross (1983) indicated that introducing the preliminary or basic design course at the Bauhaus was arguably the most significant advance in education. This six-month course was designed to support the students' development and demonstrate their innate skills. The introduction of Basic Design education at Bauhaus as a preliminary course, known as Vorkurs, was a compulsory period for continuing design education (Whitford, 1984). This preliminary course was the subject of criticism because students were encouraged to abandon their existing knowledge in order to facilitate the incorporation of new ideas and techniques. Conversely, supporters of this preliminary course asserted that its primary objective was to facilitate the realization of the creative potential inherent in each student (ibid).

According to Özkar (2004), current basic design education focuses heavily on exploring finite grammars to teach the concept of rules through pre-constructed grammars. In block-building exercises, students rely on predetermined shapes and are given preset relationships, which limit their creativity and ability to shape space. Özkar emphasizes the need for deeper pedagogical inquiry into spatial relations to better

understand and enhance creativity (ibid). Consequently, novel technological adaptations and enhanced iterations of the fundamental exercises can be developed in response to this issue.

On the other hand, the newly developing technologies offer potentials for education as the virtual environments, being places to learn together. Despite the rapid expansion of the metaverse, the studies regarding collaboration design in virtual environments, especially in the early design phases, are still limited (Yu et al., 2022). Therefore, the thesis aims to develop and examine a metaverse-based collaborative virtual model for basic design in architectural education constructed on game-based learning approach. The video-game-like model comprises projects with game elements inside (Young et al., 2012), and similarly, the term "based" refers to containing something as a part of a foundation of another. In the "metaverse-based" playground and "game-based learning" approach, metaverse and games are the basis for the learning methodology. Within this conception, the learning methodology is developed via Fabien Vienne's blocks.

Fabien Vienne (1925-2016) is an architect who has done many designs and experiments in architecture, from urban design to toy design. Vienne's CIX (1996) game blocks are one of his geometric structure studies introducing many possibilities in a box-based grid. In the CIX catalog (1996), Vienne's game blocks can be used in different fields, including education, and are suitable for digital reproduction. However, this digital adaptation and further research on how the blocks may be utilized

in education have not been made. This thesis is an effort to digitize Vienne's CIX Blocks and utilize them in the Basic Design Studio.

1.2 Aim and Scope of the Thesis

This thesis approaches digital game-based learning as a novel research area for architectural design education as a potential field for collaborative study, incorporating up-to-date virtual immersive environments. With the conception that the metaverse has the potential to be utilized in education as a comprehensive virtual world, a metaverse-based environment is created to analyze possible impacts on architectural education. Consequently, the principal focus of this thesis is to examine the subject of game-based learning, metaverse-based environments, and related subjects within the field (Figure 1).

Within this framework, the thesis introduces a Metaverse-based Playground for Architectural Education (MPAD) developed with the geometric game blocks, CIX (1996) of Fabien Vienne. MPAD represents a Digital Game-based Learning (DGBL) model for implementing basic design education in a virtual collaborative environment

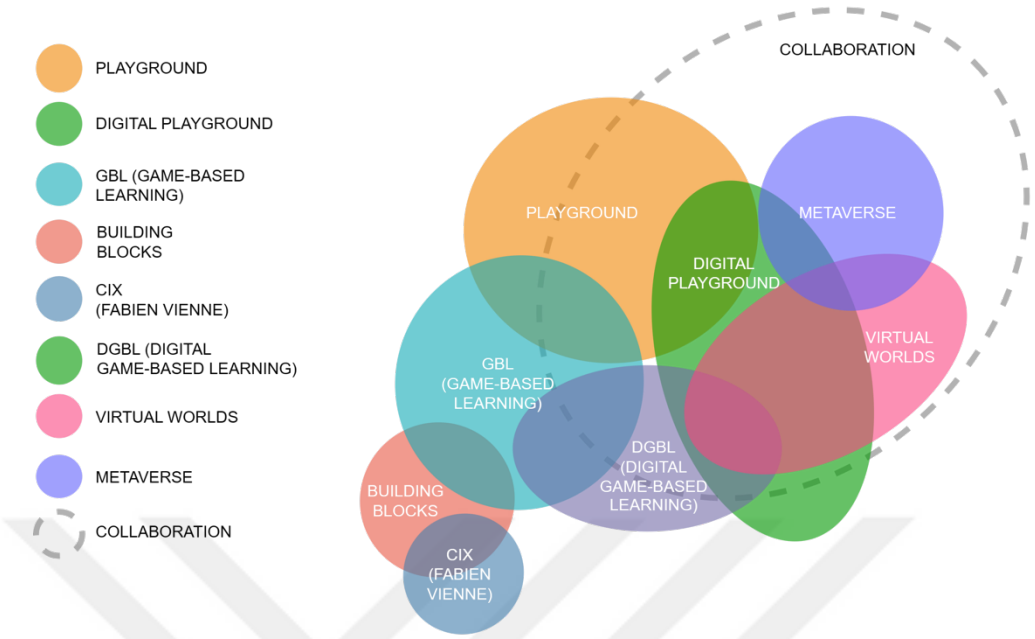


Figure 1 The main scope of the thesis (developed by the author)

It is hypothesized that MPAD will have a significantly positive and valuable impact on architecture education. This impact is expected to manifest through enhanced student engagement, improved practical skills, and spatial abilities.

This hypothesis can be broken down into the following suggestions:

1. A physically produced game block of CIX by Fabien Vienne can be an effective architectural spatial design tool when reconstructed in a virtual environment.
2. DGBL approaches can be applied in collaborative virtual environments to achieve an effective educational method.

3. Basic design education can be applied to a collaborative virtual playground environment.

This thesis aims to address the following research questions:

- How can the physical basic design studio be transferred to an online multi-user and collaborative environment?
- How does the digital game-based learning approach contribute to basic design education in architecture?
- Can a virtual collaborative learning experience support basic design education?

1.3 Methodology

MPAD represents a collaborative learning experience that takes place in a virtual playground. The game elements in the MPAD playground are predicated on Vienne's (1996) geometric study as game blocks, CIX. In its actual design, CIX comprises ten (10) parts manufactured in 1996 (A, B, C, D, E, F, G, X, Y, Z), and a total number of twenty-seven (27) elements are designed on paper. The MPAD consists of eleven CIX elements created in Rhinoceros Grasshopper software. The virtual playground is generated in the Simlab Soft VR Studio and experienced in the empirical study within VR Viewer inside Meta Oculus Quest headsets (Figure 2).

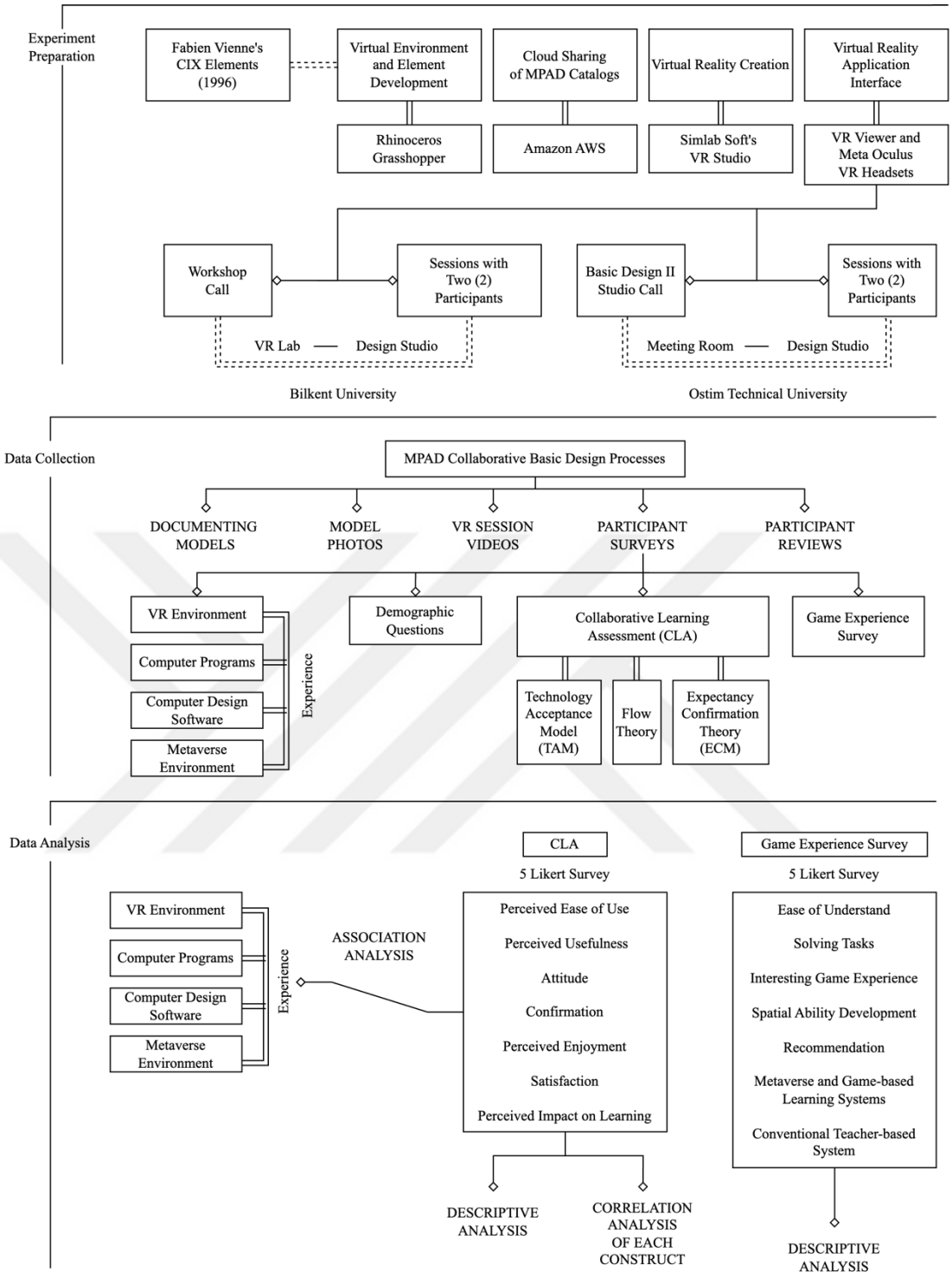


Figure 2 Flowchart of the methodology of the thesis

In the MPAD framework, an empirical experiment was conducted using the virtual environment of MPAD. The target assessment group which experiences the MPAD environment consists of undergraduate architecture students who have completed the first stage of the Basic Design course. Within this thesis's scope, students experience the basic design studio in a virtual playground based on multi-user, collaborative interaction and assess the impact of the collaborative learning, virtual collaborative experience, virtual environment of the MPAD, the flow state provided by the game-based experience, whether their expectations for MPAD are met. Students' familiarity with virtual environments is compared with the results of the assessments.

The assessments are conducted in the form of surveys and workshops. The workshops are organized into eight sessions, with four conducted at Bilkent University and the remaining four at Ostim Technical University. A total number of 40 students participated in this study and answered demographic questions, familiarity questions and post-surveys. After analyzing the participants' responses, 2 participants were excluded because of the incomplete responses. The total number of participants included in the analyses was 38.

The workshop sessions adopt a structured approach, beginning with demographic questions and continuing with students' immersion in MPAD. Each session is 30 minutes in duration, with 20 minutes assigned to application. During the sessions, data collection methods, including the documentation of the final design model, VR session videos, participant photos and survey, are employed. Prior to the sessions, participants

are invited to respond to questions concerning their previous experience with computer programs, design software, VR tools and Metaverse environments. After the sessions, students conducted the Collaborative Learning Assessment (CLA) and Game Experience Survey, which evaluated the collaborative design experience, application, and learning methodologies (Figure 2).

The final phase of data analysis involves an evaluation of the associations between responses to questions on digital familiarity and CLA, an examination of the distinct constructs of CLA, and a descriptive analysis of CLA and the Game Experience Survey. The data analyses are conducted using the statistical software program SPSS and are then reviewed in accordance with the procedures illustrated in Figure 2.

1.4 Structure of the Thesis

This study consists of five chapters. The first chapter introduces the problem statement, aim and scope, methodology, and thesis structure.

The first chapter introduces the problem statement, aim and scope of the thesis, methodology, and structure.

The second chapter initiates with definitions and classification of play and game concepts and Game-Based Learning (GBL) fundamentals in literature to display how GBL approaches have emerged and developed within the architecture discipline (Figure 3). The basics of architecture design is discussed through Bauhaus and Friedrich Froebel's approaches to education in earlier ages. His playful approach and

building blocks, also known as Froebel's gifts, are discussed and continue to be influenced by design education approaches since then.

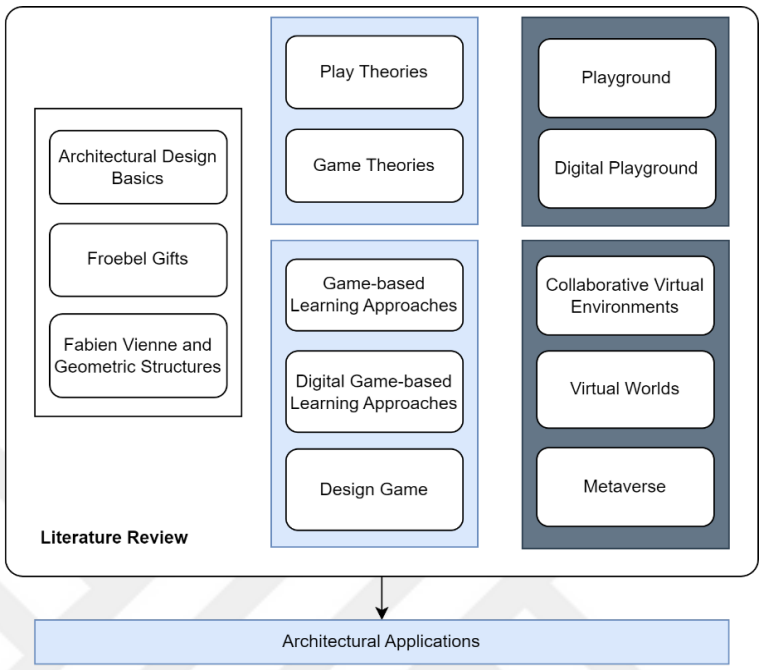


Figure 3 The literature review structure of the thesis (developed by the author)

Later in the chapter, the geometric structures of the building blocks created for learning purposes are reviewed in the center of the designs by Fabien Vienne. Vienne's perspectives will be referred to in the following chapters within the design process of the MPAD project. Lastly, the GBL's evolution into its digital equivalent, the Digital Game-Based Learning concept is reviewed, and its specific implementation in architecture education is discussed (Figure 3). Furthermore, the design-game concept is introduced. The related studies and designs in the framework of the GBL, DGBL, and design game concepts are discussed and categorized in the last part of this chapter.

The third chapter examines the concept of digital playgrounds and learning within the Metaverse, a collective virtual shared space. It is divided into two main sections: the definitions and applications of collaborative virtual environments and immersive extended reality technologies, particularly in the field of architecture (Figure 3). It provides a comprehensive overview of how digital and immersive environments are transforming learning, with a specific focus on their applications in the Metaverse and architecture. This chapter provides the necessary background to facilitate an understanding of metaverse-based playgrounds.

The fourth chapter delves into the development and assessment of the "Metaverse-based Playground for Architectural Education" (MPAD). This chapter begins by examining how the CIX is adapted into the virtual environment of MPAD, focusing on the game elements, mechanics, interface, and interaction. Moreover, this part of the chapter describes the methodology and procedural steps taken in the experimental study of MPAD. It covers the design of the experiments, the participant selection process, and the data collection methods. The aim is to provide a clear and detailed account of how the study was conducted. In this section, the theoretical frameworks used to assess collaborative learning within MPAD based on the scale model of the Technology Acceptance Model (TAM), Expectation and Confirmation Model (ECM), and Flow Theory. The section illustrates how these models help in understanding user engagement, satisfaction, and learning outcomes within the MPAD environment. Lastly, the Game Experience Survey captures various aspects of the user experience, including engagement, satisfaction, and perceived spatial ability value (Figure 4).

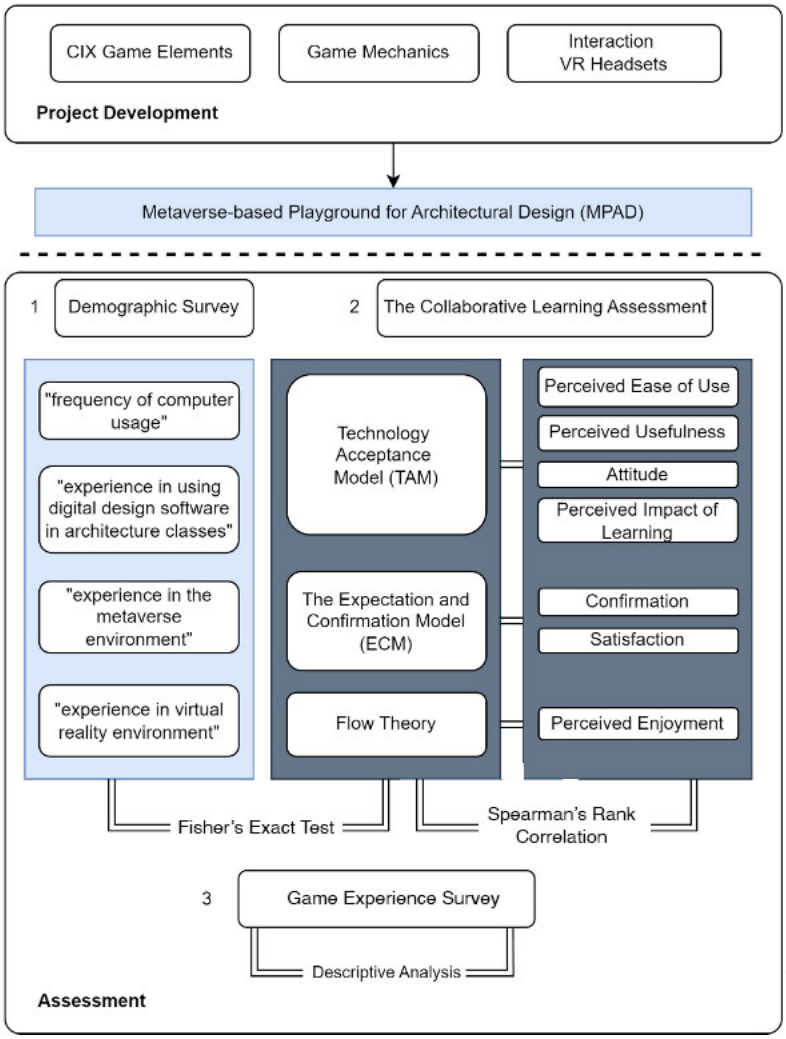


Figure 4 The MPAD development and assessment structure of the thesis (developed by the author)

The conclusion and discussion chapter presents an overview of the key findings and a comprehensive analysis of the survey results and MPAD products. Furthermore, this chapter identifies the limitations of the learning methodology and proposes recommendations for future research.

CHAPTER 2

GAME-BASED LEARNING IN ARCHITECTURAL DESIGN EDUCATION

This chapter introduces play and game concepts from various theoretical perspectives. Later, the play-based approaches in creative processes within basic design education are elucidated, tracing their implementation from Froebel to the contemporary studio environment of Vorkurs. After the implementations in the studio context, the roots and theories of the Game-Based Learning (GBL) approach are reviewed. Digital Game-Based Learning (DGBL), the digital equivalent of GBL, is reviewed and analyzed in the architectural context.

2.1 Play, Game

Numerous anthropologists, psychologists, and social scientists have delved into the concept of play and playfulness, the structure of games, play spaces, and the creative value of play. These researchers include Huizinga (1980), Caillois (2001), Vygotsky (1967), Csikszentmihalyi (1975), Avedon and Sutton-Smith (1971), Salen and Zimmerman (2003), Schell (2008), Walz (2010), McGonigal (2011) and Gee (2003).

As shown in Table 1, these theories of play are grouped according to their specific topics. The aim is to construct a definitional structure. This will provide a framework for playful activity or game design that can be used in different contexts in future research.

Table 1 *Elements in Play Theories*

Elements in Play Theories		
Element	**Description**	**Theorists**
Voluntary Participation and Free Play	Play is engaged in freely and voluntarily.	Huizinga (1980), Caillois (2001), Avedon and Sutton-Smith (1971)
Bounded in Time and Space	Play occurs within specific limits, creating a separate order.	Huizinga (1980), Salen and Zimmerman (2003), Caillois (2001)
Intrinsic Motivation and Pleasurable Experience	Play is inherently enjoyable and is pursued for its intrinsic rewards.	Csikszentmihalyi (1975), Gee (2003), Caillois (2001)
Cognitive and Emotional Involvement	Play engages cognitive and emotional processes, fostering creativity and emotional expression.	Csikszentmihalyi (1975), Schell (2008), McGonigal (2011)
Rule Based System	Play has rules, offering structure and restraining impulsive actions.	Vygotsky (1967), Caillois (2001)
Movement - Kinesis	Play, whether physical or virtual, is fundamentally about movement.	Walz (2010)
Engagement and Immersion	Play can lead to deep engagement and a state of flow where players are fully absorbed.	Csikszentmihalyi (1975), Schell (2008), McGonigal (2011)
Social and Cultural Context	Play reflects and shapes cultural values and most evidently in social play and interaction.	Huizinga (1980)
Imaginary	Play involves creating an imaginary scenario, often seen as make-believe.	Vygotsky (1967), Caillois (2001)

The game elements are explored covering the multifaceted concept of play through voluntary participation and free play, time-space limitation, intrinsic motivation, imagination, cognitive process, rule-based system, movement, immersion, social aspects and imaginary environment.

Voluntary Participation and Free Play

Huizinga (1980) describes the play as a fundamental aspect of life, recognizable to everyone, from humans to animals. It's a comprehensive and undeniable concept. Before Huizinga's theories, it was argued that play has a biological purpose for a specific purpose other than play itself. Huizinga (1980) describes play as a voluntary activity that cannot be accomplished with external forces, such as moral duty or necessity.

Freedom is the first of play's main characteristics, which must differ from the basic instincts of children and animal play (Huizinga, 1980). The psychologist Csikszentmihalyi (1975) uses the term "autotelic" activity instead of play, which originates from auto (self) and telos (goal) words that have Greek roots, meaning expecting no outer goals or conventional awards rather than itself (Gray, 2015). Caillois's definition of play is free, separate, and uncertain with its own time and spatial limits, unproductive by creating no good without an end with an identical situation (Caillois, 2001).

Avedon and Sutton-Smith (1971) state that play is often regarded as a unique and individual activity characterized by its ephemeral nature. Unlike games, play is less

systematic and has open-ended outcomes. Its inherent freedom and spontaneity enable creativity and personal expression without the limitations of set rules or goals. The unstructured and unpredictable nature of play makes each instance distinct and impossible to replicate exactly. This individualistic character of play emphasizes its role in personal enjoyment and exploration, setting it apart from games, which are more structured and focused on outcomes (Avedon and Sutton-Smith, 1971).

Movement and Kinesis

According to Walz (2010), play is fundamentally about movement, and this movement connects players with others, game elements, and environments that interact with them. This perspective contrasts with structured play models by emphasizing play activities' fluid, dynamic nature.

Imaginary

According to Russian psychologist Vygotsky (1967), play always involves the creation of an imaginary situation. Caillois presents play as a form of secondary reality, often perceived as make-believe (Caillois, 2001).

Rule Based System

According to Csikszentmihalyi (1975), in almost all autotelic activities, the participants experience exploration, discovery, newness, and, at the same time, problem-solving and challenges. Caillois expands upon Huizinga's definition of play, asserting that it is governed by rules (Caillois, 2001). Vygotsky (1967) emphasizes that play allows players to act freely and participate voluntarily; however, it is not a

freeform activity. In his arguments, play always contains rules providing structure and guidance. The existence of the rules prevents players from acting with instant impulses.

Csikszentmihalyi (2014) conceptualizes play not as child's play but as structured activities like rock climbing, dance performance, music composition, gambling, basketball, rituals, and so forth. Csikszentmihalyi (2014) theorizes the "flow state," suggesting that games are examples of flow activities and that play itself is a flow experience. Flow mainly occurs in activities with clearly stated rules and structured environments. This allows individuals to maintain control over their actions. Flow can be accounted for a spectrum that extends from simple, automatic actions such as doodling to tasks that challenge a person’s physical and intellectual capabilities (Csikszentmihalyi, 1975).

Social and Cultural Context

In Huizinga's definitions (1980), the social part of play becomes prominent as it creates a sacred sphere in which each attempt to play tends to develop its play communities, "phratria" (p.12). All the primary archetypal actions of society have been shaped by play, beginning with language through its play of words, through myths, which are the products of the imagination of the external world, and finally through rituals as the representation, mystical repetition and identification of spiritual events.

The relationship between culture and play is most evident in higher forms of social play that involve complex, structured activities of teams such as sports, games, and

other group activities where rules and cooperation or competition are the key elements. Solitary play, on the other hand, has a more limited impact on culture and is less likely to produce shared experiences due to lacking the social interaction and cohesion (Huizinga, 1980).

Game

Caillois offers one of the earliest classifications in game studies (Caillois, 2001). He introduces the concepts of paidia and ludus as two poles on a spectrum of play. *Paidia* is characterized by turbulence, spontaneity, free improvisation, and unstructured play. In contrast, *ludus* involves structured, rule-bound play characterized by obstacles, strategic planning, and calculated efforts. According to Caillois, paidia and ludus are not rigid categories but rather modes of play that exist on a spectrum; as the presence of one increase, the presence of the other decreases. He categorizes games to highlight the diverse possibilities for human experiences. He proposes four categories across different contexts: agon (competition), alea (chance), mimicry (simulation), and ilinx (vertigo, involving rapid movements and a state of disorder) (Table 2) (ibid).

Table 2 *Caillois' Categorization of Games*

Caillois' Categories of Games			
Ludus = Structured, Rule-bound, Calculated			
Paidia = Turbulence, Spontaneity, Free Improvisation, and Unstructured Play			
Agon (Competition)	Alea (Chance)	Mimicry (Simulation)	Illinx (Vertigo)

Following Caillois, a multitude of theories have been proposed with the objective of defining and categorizing games. These theories, which originate from the works of individuals such as Crawford (1984), Costikyan (1994), Avedon and Sutton-Smith

(1971), Zyda (2005), Salen and Zimmerman (2003), McGonigal (2011), Carse (1986), Kapp (2012) and Aldrich (2009) differentiate between play activity and specific game definitions. Table 3 presents a classification of game theories according to their specific topics. This analysis enables a clear understanding of the structure of the game.

Table 3 *Elements in Game Theories*

Elements in Game Theories		
Thematic Element	Description	Theorists
Rule-Based Structure	Defined by formal rules that guide play and distinguish it from real life.	Caillois (2001), Salen and Zimmerman (2003), Costikyan (1994), Kapp (2012), Avedon and Sutton-Smith (1971), Vygotsky (1967), McGonigal (2011)
Free Unstructured Play	While governed by rules, games allow for adaptability and fluid experiences.	Caillois (2001), Carse (1986)
Bounded in Time and Space	Games occur within specific limits, creating a separate order.	Caillois (2001), Carse (1986)
Goal and Outcome	In games, the outcome determines a player's status and gives meaning and direction to their actions. It's a definitive result achieved by following the game rules, involving a conflict of forces within a repeatable pattern.	Kapp (2012), Costikyan (1994), Schell (2008), Avedon and Sutton-Smith (1971), Salen and Zimmerman (2003), McGonigal (2011)
Balance of Challenge and Skill	Successful games require balancing the challenges presented and the player's skills, maintaining engagement and interest.	Crawford (1984), Salen and Zimmerman (2003), McGonigal (2011), Caillois (2001)
Dynamic Interaction and Participation	Games involve interactive dynamics between players and the game environment.	Salen and Zimmerman (2003), Schell (2008), Crawford (1984), Aldrich (2009), Kapp (2012), Costikyan (1994)
Pleasurable Experience	Games are inherently enjoyable and provide pleasure.	Caillois (2001), Avedon and Sutton-Smith (1971), Kapp (2012), Carse (1986), Zyda (2005)
Feedback	In games, positive or negative feedback is usually immediate and straightforward.	Kapp (2012), McGonigal (2011)

Rule-Based Structure

Vygotsky (1967) conceptualizes play as a goal-directed activity in which those goals determine the game. Costikyan (1994) states that the games are about decision-making, where players use a set of rules to generate their own outcomes. The objective of every player in a game is to make decisions.

Avedon and Sutton-Smith (1971) describe games as inherently systematic due to their structured patterns and predictable outcomes, allowing recreation across different contexts for similar experiences. Their repeatability is ensured by the consistent rules and procedures applied. Salen and Zimmerman (2003) mention that games are formal rule systems. The rules establish the framework defining the actions a player is permitted and not permitted to perform.

McGonigal (2011) states that the rules set boundaries for player strategies to reach the goal. In this way, rules stimulate creativity and strategic thinking by restricting apparent paths to the goal, thus exploring untapped possibilities. Costikyan (1994) exemplifies that the appeal of games like chess lies not in their visuals or role-playing elements but in the need for strategic thinking and decision-making within objectives and constraints.

Structured yet Flexible

Carse (1986) classifies play into two categories: finite and infinite. Finite games are played with the objective of winning, and they continue until a winner is declared. In

contrast, infinite games are played to continue the game itself without a definitive end. In other words, infinite play only occurs when players engage freely and willingly (Carse, 1986). This kind of play correlates with Caillois' (2001) Paidia, a turbulent, improvisational, and unstructured play.

Bounded in Time and Space

In conceptualizing the game as two directions by Carse (1986), a finite game structure, players play within established boundaries. Finite games are constrained by external factors like time, space, and number and have intrinsic rules that limit player interactions. In contrast, infinite players interact with and potentially change their boundaries in the game. In an infinite game, time is not decided by external standards but is created within the game itself, making it impossible to determine its duration. Multiple worlds can exist within the infinite games.

Outcomes

Decisions in a game without a goal lack purpose; therefore, games need goals to provide meaning and direction (Costikyan, 1994). McGonigal (2011) claims that the objective provides players with a clear target to pursue, guiding their actions and maintaining their engagement in the game. It provides players with a sense of direction.

At its core, a game consists of a repeatable pattern, a conflict between forces, and a definitive outcome, all bounded by rules. Players willingly follow set rules to achieve

a goal in a game, but there's no guarantee of reaching it (Avedon and Sutton-Smith, 1971). Games have a measurable objective, with players either winning, losing, or attaining a specific score upon completion. This quantifiable result distinguishes games from other play events (Salen and Zimmerman, 2003). Kapp (2012) states that when the game has a definitive outcome, it differentiates itself from mere play, making it a viable tool for training.

Dynamic Interaction

Crawford (1984) states that the distinguishing factor that separates a game from a non-game activity is the presence of an interactive element. Interaction introduces a social aspect, changing the game's challenge from technical to interpersonal. While solving a puzzle is purely technical, playing a game like chess involves competing against another person. Interaction changes the nature of the challenge from static to dynamic. In a game, the challenge changes as the opponent reacts to the player's actions, unlike in a puzzle, where the challenge is always the same (Crawford, 1984). According to Kapp (2012), a game is an interconnected system in which players interact with content and each other. The interconnection of several critical elements creates an engaging and educational experience.

Like the interaction, games require active participation from the audience, unlike traditional art forms such as painting and movies. In this sense, the game is like a stage where the players create their performances. Therefore, games are a democratic art form, reflecting active engagement (Costikyan, 1994).

Balance of Challenge and Skill

Conflict is a vital element in games, arising from in-game interactions, presenting in various forms, from direct to indirect and violent to nonviolent (Crawford, 1984). All games involve challenges and competition, which are crucial components of games. The struggle can manifest in various ways, from collaboration to competition, from an individual challenge against the game system to a multiplayer social conflict (Salen and Zimmerman, 2003). The challenge-driven environment contributes to the unique structure of the gaming environment (Kapp, 2012).

Pleasurable Experience

Games evoke strong emotional reactions, enhancing their immersive potential. Kapp states that game elements create a compelling experience (Kapp, 2012). Carse (1986) emphasizes that the essence of any game, be it finite or infinite, lies in its voluntary nature. Zyda (2005) defines digital games as a mental competition conducted with a computer, where specific rules are followed for enjoyment, leisure, or to win a prize. To McGonigal (2011), the game requires the active and willing participation of all players, who must understand and accept the established goals, rules, and feedback. This mutual understanding enables individuals to engage in the game together, and the freedom to join or leave the game ensures a safe, enjoyable experience, even when the game is challenging.

Feedback

The game environment operates under certain rules and immediate feedback, which is crucial for engagement (Kapp, 2012). The feedback system provides players with information regarding their progress towards the desired outcome. This system may be presented to players through levels, points, scores, and progress bars. It may indicate the end of the game in its simplest form. Providing players with feedback motivates them by demonstrating that the desired outcome is achievable (McGonigal, 2011).

2.1.1 Game-Based Learning (GBL) Approach

Vygotsky (1967) regarded play as a cognitive process that contributes to a child's development. He highlighted the developmental role of play, primarily in the preschool years. However, he also observed that play evolves into an attitude towards reality during school or work periods.

Kapp (2012) states that one core element that sets games apart from mere "play" is the defined end state or measurable outcome. This characteristic is particularly beneficial in educational contexts, making games an optimal tool for instructional settings.

Bulgarelli and Bianquin (2017) define play-like activities as any activities conducted in playful settings or with a playful attitude, using playful tools (such as toys or games) to achieve an external objective (such as education or rehabilitation). Play-like

activities can also be described as play-based or game-based, depending on the context in which they are used.

Game-based learning (GBL) is typically characterized as a form of gameplay with established learning outcomes, often within a digital framework. The design process of GBL requires a delicate balance between the representation of the subject matter and the prioritization of gameplay (Plass et al., 2015).

Al-Azawi, R., and others (2016) point out the increased use of GBLs for,

- unengaging and technical materials,
- challenging subject matter,
- inaccessible audiences,
- complicated assessments and certifications,
- intricate comprehension processes,
- complex “what-if” scenarios,
- strategy formulation and communication,
- enhancing student motivation and interest in learning.

The game-based learning approach can be developed based on the traditional learning models. In the GBL research, Kolb’s experiential learning model (1984) first proposed in 1984, continues to serve as a foundational framework for understanding how individuals learn through direct experiences, reflection, and active experimentation. The model is inspired primarily by the theories of Vygotsky (1967) and Piaget (1971).

By actively participating in experiential learning activities, students can enhance learning outcomes, develop critical thinking skills, and apply theoretical knowledge to real-world contexts (1984).

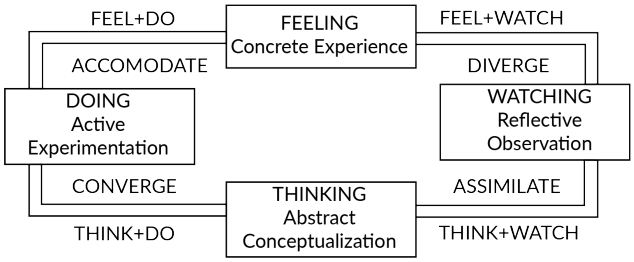


Figure 5 Experiential Learning Cycle (adapted from Kolb, 1984)

Kolb's experiential learning theory (1984) explains that knowledge is created by experiencing and then transforming that experience. There are two ways to experience something: directly (concrete experience) or by understanding it conceptually (abstract conceptualization). Similarly, there are two ways to transform this experience: observing it (reflective observation) or experiencing it (active experimentation). Combining these methods in different ways leads to four types of knowledge: divergent knowledge (experiencing directly and reflecting), assimilative knowledge (understanding conceptually and reflecting), convergent knowledge (understanding conceptually and experimenting), and accommodative knowledge (experiencing directly and experimenting) (ibid). Figure 5 simplifies and adapts the cycle by showing these types as distinct learning styles based on feeling, watching, thinking, and doing combinations.

Hsieh et al. (2016) observed that learners in a flow state showed higher performance levels. Csikszentmihalyi (2014) puts forth the "flow state" concept, proposing that games exemplify flow activities and that play itself serves as a flow experience. He theorizes that the flow phenomenon involves six elements: (1) centering of attention, (2) merging of action and awareness, (3) loss of ego, (4) control of action and environment, (5) demands for action and clear feedback, and (6) autotelic nature.

The flow is characterized by a narrowing of consciousness, accompanied by focused attention on the present moment and the environment (Csikszentmihalyi, 2014). In the flow state, the individual is not subject to the need for conscious reflection and as a result, feedback is clear and immediate, providing the opportunity for automatic responses. The flow state is also crucial for democratic and fluent gameplay when the players do not need to negotiate between roles since rules are freely accepted. Competition, material gains, and physical danger are some elements that can enhance engagement in the activities, fostering a state of pure involvement. In an ideal flow experience, involvement can be achieved without considering the results (ibid).

Malone and Lepper (1987) have proposed a detailed classification of individual motivations for learning in “The Taxonomy of Intrinsic Motivations,” which can be leveraged to create more captivating educational settings. The individual motivations encompass four main areas: Challenge, which involves goal-setting, unexpected outcomes, performance feedback, and self-esteem; Curiosity, which is further segmented into sensory and cognitive aspects; Control, which entails aspects of

probability, choice, and power; and Imagination, which includes sensory and cognitive components, as well as endogeneity (Table 4).

Table 4 *Individual and Interpersonal Motivations for Learning*

Individual Motivations	**Subcategories**		
Challenge	1a. Goals, 1b. Unexpected Outcomes, 1c. Performance Feedback, 1d. Self-esteem		
Curiosity	2a. Sensory, 2b. Cognitive		
Control	3a. Probability, 3b. Choice, 3c. Power		
Imagination	4a. Sensory, 4b. Cognitive, 4c. Endogeneity		
Interpersonal Motivations	**Subcategories**		
	Competition	Cooperation	Recognition

Note. Adapted from Malone and Lepper (1987).

In addition to intrinsic motivation, they propose interpersonal motivation principles, which refer to the social aspects that can motivate learning, including cooperation, competition, and recognition. Cooperation activities can be designed in independent parts that require cooperation tasks. Competition is fostered by activities where participants' actions affect each other. Recognition depends on activities where learners' efforts are socially valued (Malone and Lepper, 1987).

2.1.2 Digital Game-Based Learning (DGBL) Approach

Many studies have been developed in the literature to question the relationship between spatial skills and digital games. Gee (2003) identifies 36 learning principles encouraged by digital games. These include active, critical, and exploration-based

learning, developing one's potential through an intrinsic reward system, enhancing context-dependent skills, appreciating design aspects, experiencing ongoing mastery processes, and many more.

De Castell and others (2015) reveal the impact of the background of digital game experience on spatial cognitive skills in STEM (Science, Technology, Engineering, and Mathematics fields) education. Recent research further suggests that digital games facilitate understanding of complex systems, promote independent thinking, and foster self and cultural expression (Bogost, 2005).

Prensky (2003) asserts that the digital game-based learning approach (DGBL) can be employed for the purposes of communication and strategy development in complex, challenging, and technical subjects where intrinsic motivation is lacking.

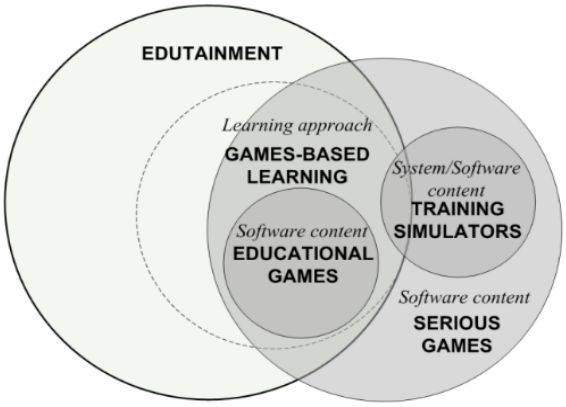


Figure 6 "The game-based learning frame in the domain of edutainment, educational games, educational simulators, and serious games," as depicted in the diagram created by Tang et al. (2009)

DGBL is now a well-established field of study with a diverse scope, encompassing numerous disciplines and game genres. The terminology and literature within DGBL can be classified into sub-areas, which have evolved over time, giving rise to new concepts (Figure 6).

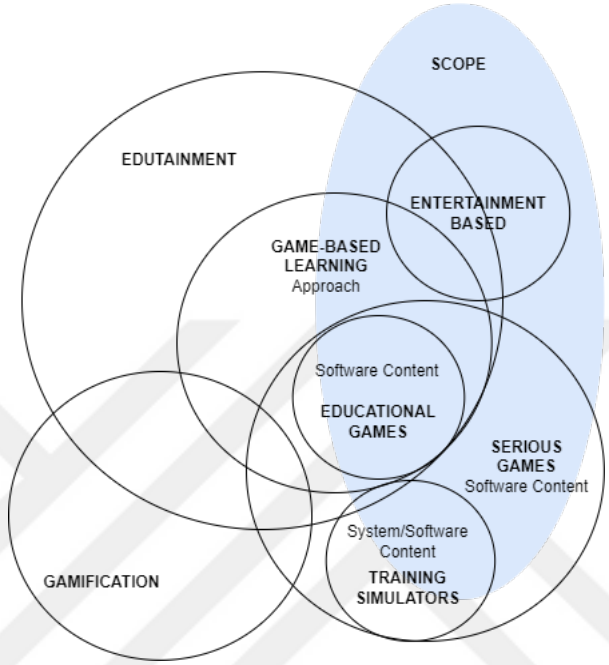


Figure 7 An adaptation of Tang et al. (2009) diagram of GBL extent in this study.

It is necessary to analyze the concepts within this field to relate this study to the field of DGBL and to situate it within the existing literature. The structure of the GBL framework presented in this thesis follows the format shown in Figure 7.

Edutainment

Educational games, commonly called "edutainment," first appeared in 1983, but significant research in this area only began in the 1990s (De Lope & Medina-Medina,

2017). According to Charsky (2010), edutainment applications are often seen as the least effective form of education because they tend to have low educational standards and lack engaging gameplay. As video games have evolved from simple titles like Space Invaders to complex games like Civilization, the edutainment genre has similarly progressed alongside the development of serious games.

Serious Games

Huizinga (1980), considered a pioneer in game studies, defines play as free activities set apart from everyday life. Although the play is characterized by a lack of seriousness, it simultaneously immerses the player in a highly engaging manner. The concept of serious games was first introduced by Clark Abt in 1970 in the context of non-digital games. Abt (1970) argued that games could serve both serious and casual purposes. He noted that while these games are not primarily intended for entertainment, they are not devoid of it either. Serious games, designed mainly for educational purposes, are expected to entertain in a way that appeals to large audiences and engages players (Bellotti et al., 2013).

Zyda (2005) defines serious games as mental competitions that use entertainment within set rules to achieve goals in management, education, health, defense, public policy, and strategic communication. Unlike typical video or computer games, serious games combine art, storyline, and software with pedagogy, primarily emphasizing entertainment, supported by educational elements to enhance the storyline.

Gamification

Gamification is an approach to game-based thinking that is employed in a multitude of fields. However, it is often confused with game-based learning, although the two are, in fact, significantly different. In contrast to GBL, a form of gameplay designed with specific learning outcomes often within a digital environment, gamification integrates game elements such as points, badges, and leaderboards to motivate and engage learners in tasks that may not be inherently appealing (Plass et al., 2015). In gamification, game elements such as avatars, feedback, rating, and three-dimensional environment are re-functionalized in different functions (Deterding et al., 2011).

Bogost (2015) asserts that gamification primarily focuses on trivial elements, including awarding points and using leaderboards. He maintains that it does not adequately address the complexity of simultaneous design and play simulations, which should be the central focus of any gamification strategy. Bogost further posits that the relationship between gamification and games is poorly understood and applied, leading to the perception that games for gamification are merely tools to gain business benefits rather than experiences (ibid).

Training Simulators

Applications that simulate real life have been demonstrated to be highly effective in education due to the roles they assign to participants and the environments and situations they create. They also enhance learning through the spatial experiences they

offer. According to Gredler (1996), simulations can be divided into two broad categories: experimental and symbolic. Experimental simulations assign specific roles and responsibilities to participants in an entirely novel, unique reality, which can be considered a dynamic field study. Symbolic simulations aim to simulate challenging and costly situations that participants cannot experience in real life or to take responsibility for complex problems. Symbolic simulations aim to discover, understand, and theorize about events by providing participants with interactive processes where they can perform a multitude of different actions (ibid).

2.2 Architectural Basic Design from Froebel to Building Blocks

The Basic Design course was designed to challenge students' preconceived notions of art and design by encouraging them to engage with fundamental characteristics such as materials, colours, textures, structures and compositions (Cross, 1983). The roots of basic design education as a means of individual development can be traced back to the early 19th-century educator Friedrich Froebel, who emphasized the value of hands-on learning through play. Froebel's pedagogical approach involved using the hands and bodies of learners in guided activities and engaging with adaptable toys such as building blocks (Özkar, 2017).

2.2.1 Basics of Architectural Design from Froebel Gifts

Huizinga mentions the various aspects of play and the terms used to describe it, which are largely derived from aesthetics. Those terms aim to articulate the influence of beauty, such as tension, equilibrium, balance, contrast, variation, resolution, and so

forth. He emphasized the captivating effect of play in its more developed forms, which arises from its ordered, rhythmic, and harmonious nature, considered high forms of aesthetic perception (Huizinga, 1980). These terms related to aesthetic understanding are highly mentioned in the writings about the visual compositions of the leading Gestalt psychologist, Arnheim (1974). At the same time, they remain one of the main elements that form the structure of basic design education.

In Gestalt theories, Arnheim (1974) mentions understanding the distinction and the relation between parts and whole and how the mind completes the coherent whole with the pieces. Rather than being solely a consequence of the individual components, the overall structure of a system significantly influences the characteristics of the individual components. Conversely, these characteristics can also influence the system's structure. The appearance of any “genuine” part significantly depends on the structure of the whole, and the whole is influenced by the nature of its real parts, implying that no part of an artwork or structure is entirely independent (ibid).

A balanced composition implies a state of equilibrium between various elements, including shape, direction, and location. In such a composition, no change seems possible, and the whole appears to possess a quality of "necessity" in all its parts. In contrast, an unbalanced composition appears temporary and unsettled. Consequently, the elements of the composition tend to rearrange to achieve a state of greater structural coherence (Arnheim, 1974).

Today’s basic design studios in architectural education’s precedents trace back to the Bauhaus times. Bauhaus was established by Walter Gropius in 1919, initially in Weimar, Germany, until 1925, then in Dessau until 1932, and lastly in Berlin until its closure in 1933. It revolutionized art and design education with its novel perspective on production, techniques, and technological approaches.

Johannes Itten pioneered the Vorkurs, a foundational design course at Bauhaus, intended to broaden students' perspectives by challenging their preconceptions. Itten's approach emphasized hands-on experimentation with various forms, colors, and textures across dimensions inspired by analyses of artworks. This experimental method was complemented by theoretical instruction from Paul Klee and Wassily Kandinsky, who taught compulsory courses in color and form. Klee continued until 1931, and Kandinsky until the school's closure in 1933. The exploration of color and form remained central throughout the course's history (Whitford, 1984).

Another revolutionary architectural and art school was in action between 1920-1930, in the avant-garde era in Moscow, known as “Soviet Bauhaus,” the Vkhutemas. Its creation resulted from the Second Reform of Artistic Education, intending to prepare highly qualified master artists from all areas and types of art, architecture, and design for the industry (Vkhutemas, 2020).

As expressed by Golosov (2020), the basic design education curriculum of the Vkhutemas covers fundamental architectural concepts and principles, including the significance of architecture, architectural mass and form, and the importance of

detailing and spatial relationships. It involves practical exercises in composing structures and emphasizes using expression tools to demonstrate structures' strength, solidity, and intellectual components. The significance of spatial relationships and rhythm in architecture is also highlighted.

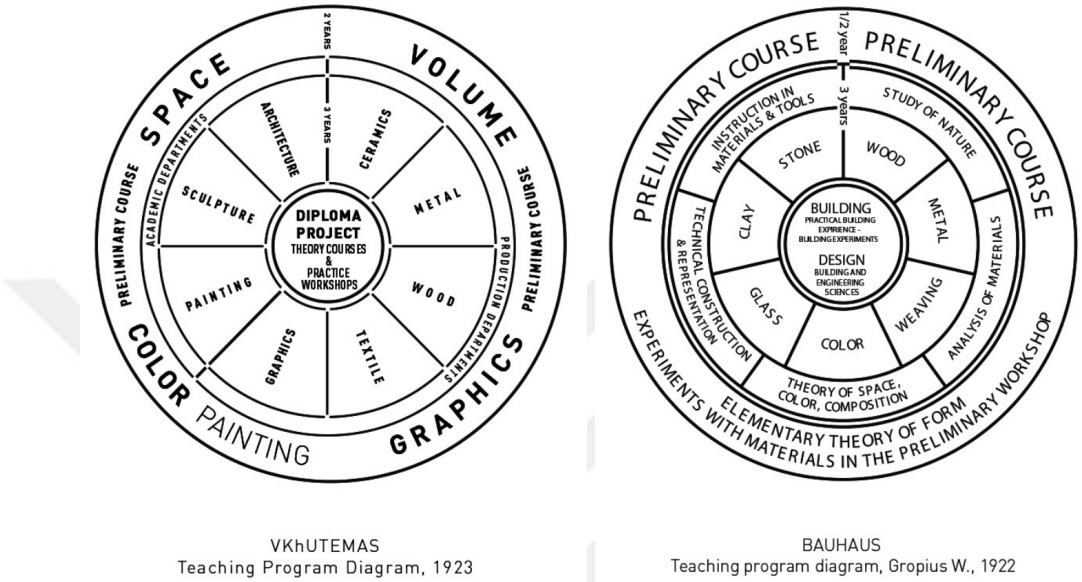


Figure 8 Vkhutemas (1923) and Bauhaus (1922) teaching program diagram of Basic Design (Bokov, 2018).

Vkhutemas had a core curriculum of basic design education that included courses like "Space," "Volume," "Color," and "Graphics," which formed the foundation of design education (Bokov, 2018). Although the Vorkurs at the Bauhaus emphasized basic form studies and material research, the main course at Vkhutemas was organized around abstract formal elements such as graphic lines and spatial forms. The divergence between the curricula of the two prominent schools is illustrated in Figure 8.

Initially, Itten's course in Bauhaus focuses on playing with different forms, colors, and textures in two and three dimensions. The method of play Itten emphasizes in the Vorkurs, as well as the other Bauhaus teachers, derives from the ideas and gifts of Friedrich Froebel (Whitford, 1984). Walz (2010) states that modern design and art are rooted in Froebel's use of formal pedagogy through kindergarten gifts. The key aspects of modernity originate from the play with the geometric forms.

The preliminary course simplifies the design elements, and the artist intentionally uses elementary concepts. Bauhaus artists adopted a sequence in the preliminary course to maintain abstractness. Within this simplicity, it is accepted that a line is a more elementary element than a two-dimensional closed shape and is more basic than a three-dimensional form. Therefore, the sequence follows line, shape, and three-dimensional form order. Even though many Bauhaus pioneers adopted the theories of Froebel, they did not follow his order, which is 3D shape, 2D shape, and line. This usage comes from understanding the abstractness of the forms from three-dimensional reality to two-dimensional line (Kim, 2006).

Friedrich Froebel

Friedrich Froebel's educational philosophy emphasized understanding the universe through the exploration of "parts of wholes." He designed educational tools known as gifts, which represent the external world, and occupations, which are the strategies from the inner world (Özkar, 2017). Froebel Gifts are tools based on geometric principles that develop children's ability to produce new things with existing materials.

They consist of fabric balls, wooden blocks, cubes, rings, pyramids, spheres, and cylinders (Bloch & Choi, 1990; Froebel, 1912). They engage in activities known as occupations, like molding, carving, weaving, cutting, and folding, thereby exploring part-whole dynamics. Froebel's concept of part-whole dynamics was integral to his educational approach to fostering personal perception (Özkar, 2017).

In his seminal work, Stiny (1980) emphasizes the relationship between kindergarten and the studio. He states that Froebel's gifts are ideal for exploring spatial design possibilities (Figure 9).

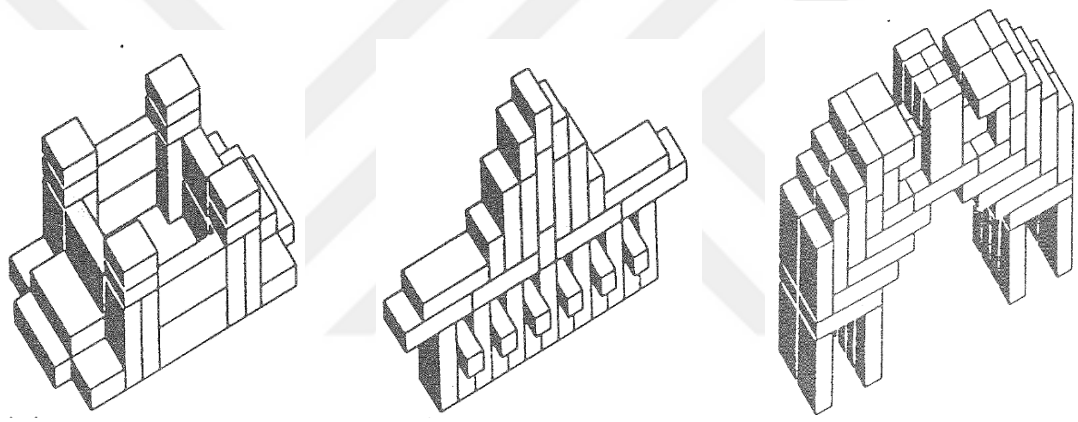


Figure 9 The possibilities of Froebel gifts include the bath, church organ, and artificial building (from left to right) (Stiny, 1980).

The kindergarten method, which resembles the highly effective studio method used in architecture and design schools, employs a vocabulary of building elements and a system of form categories. This combination creates a "language of designs," where various elements are intuitively arranged according to the categories (Stiny, 1980). By altering the vocabulary or categories, different design languages can be taught.

Similarly, the studio method employs architectural elements and categories related to architectural programs, building types, historical styles, and aesthetic principles to teach these design languages (Figure 10). As in the kindergarten tradition, architecture students initially explore their vocabulary and design language with the master architects.

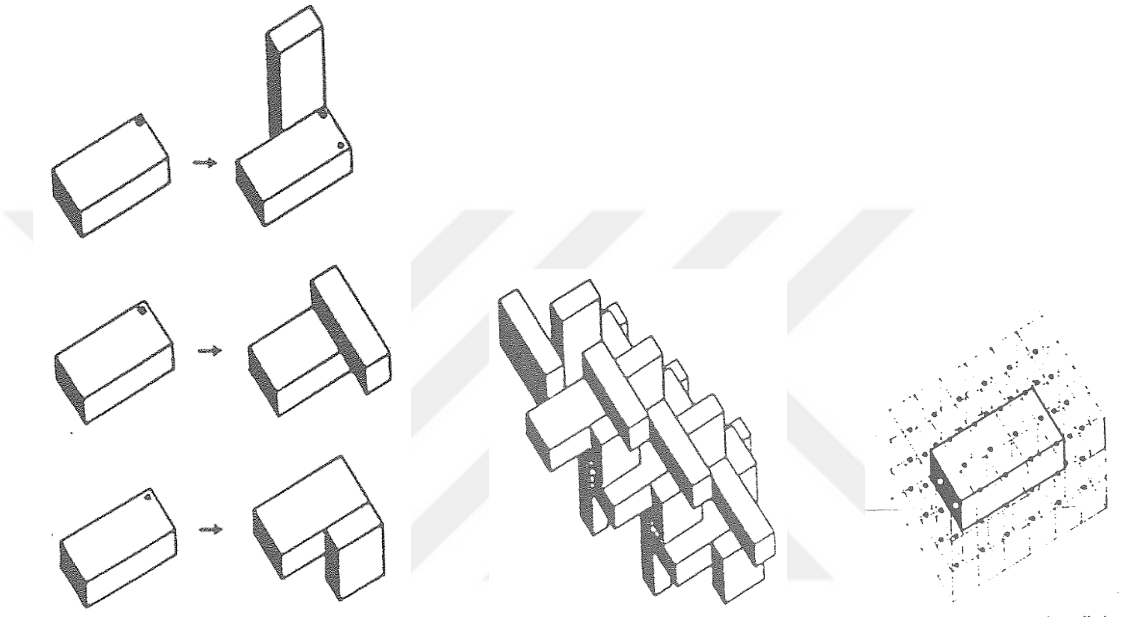


Figure 10 Shape rules are applied to the various spatial constructions based on the Froebel Gifts' (on the left), a gift in an imaginary cubical grid (on the right) (Stiny, 1980).

Froebel uses the grids to complement the gifts as a network of different scaled square units. The square units of the grid represent the pedagogical use of abstraction. The grids provide a guideline for the gifts decided on from the outset. The precision of the guideline is a combination of rules that do not allow any manipulation throughout the process. The grid's rigidity is primarily due to the fact that its basic unit is a square in

a specific relationship to its neighbors. The grid indicates all possible combinations that can be created using the unit, the square (Özkar, 2017).

Table 5 demonstrates that Froebel's pedagogical kindergarten projection has certain values (Brosterman, 2001).

Table 5 *Froebel's pedagogical kindergarten projection*

Froebel's pedagogical kindergarten projection
Enhancing motor skills through gymnastic games.
Hands-on activities for sensory and hand labor skills.
Encouraging creativity and artistic abilities.
Stimulating intellectual growth through curiosity and comparison.
Teaching responsibility and ethics through activities like gardening.
Expressing emotions and appreciating aesthetics through singing.
Fostering social virtues through community participation.
Exploring spiritual needs and the search for higher meaning.

Note. Adapted from Brosterman (2001).

In his Testament (1957), a well-known architect, Frank Lloyd Wright, mentions how Froebel's educational philosophy profoundly influenced him starting from kindergarten. He states that the gifts present a system that is the fundamental geometry behind nature and the basis of the design. Using smooth maple blocks and cardboard triangles fostered an understanding of fundamental shapes and their significance—square for integrity, circle for infinity, and triangle for aspiration. Froebel's teaching methodology emphasizes understanding the fundamental, cosmic geometric elements behind natural appearances. The early training in combining these elements into imaginative patterns developed a sense of the rhythmic structure of nature and an

inherent understanding of cause-and-effect that became fundamental to the Wrights' later design work (Wright, 1957).

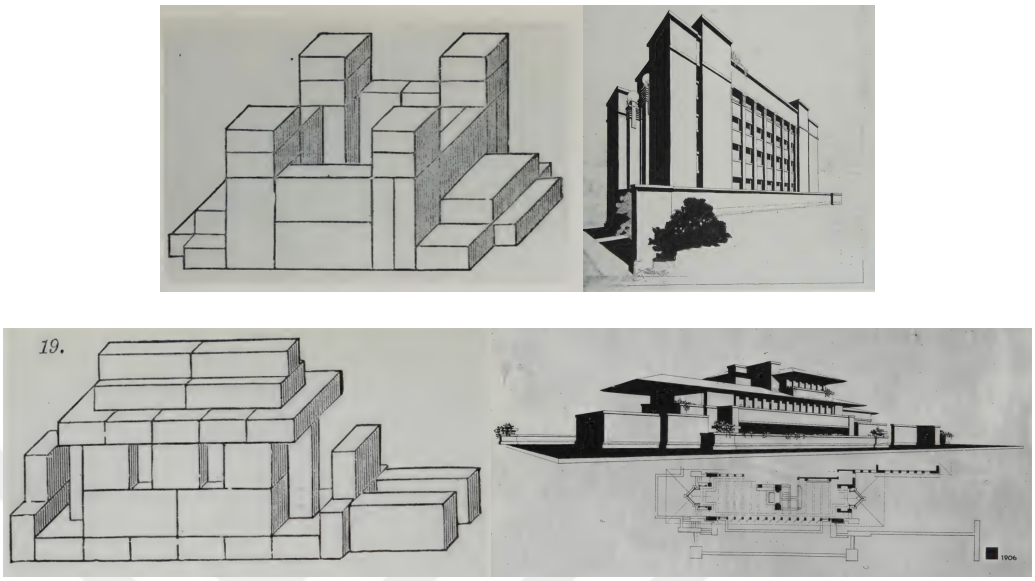


Figure 11 Larkin Company Administration Building (1902) and the structure with the sixth gift (on the top); Frederick C. Robie House (1906) and structure with the sixth gift (at the bottom) (Brosterman, 2001).

Walz (2010) states that architecture results from structured play of basic shapes and patterns. Referring to Froebel's primary shapes and play structure, the architectural works of Frank Lloyd Wright and Le Corbusier demonstrate the influence of Froebel's pedagogical principles. The examples of the buildings of Wright and the Froebel structures' relationship are illustrated in the Figure 11.

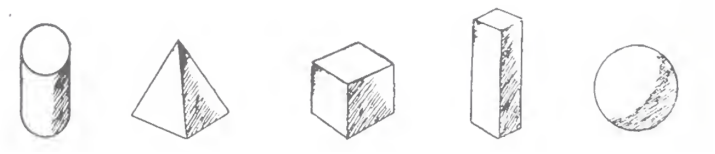


Figure 12 Le Corbusier's basic volumetric mass sketch from Towards A New Architecture (1986)

Wright and Le Corbusier increasingly employed explicit geometric proportional systems in their works (Figure 12). Wright aimed for "unity" in his designs, using the proportioned angles, cubes, triangles, and circle geometries of the basic Froebel's gifts. Wright also adapted Froebel's system into the grids of his plans, which also influenced the three-dimensional rectangular solids in his design. On the other hand, Le Corbusier sought "harmony," applying his Modulor system to all his creations (Brosterman, 2001).

2.2.2 Building Blocks and Architecture

In his book "Laws, Book One," Plato mentions that the ideal early education involves using playtime to foster a strong affinity for the future occupation, leading to excellence in adulthood. Children should be surrounded by tools and engage in activities related to both in work and playful contexts, using simplified versions of professional tools; for example, future architects (builders) should construct toy houses using miniature versions of real tools. Children's games should be used to guide their interests and desires towards their future adult roles (Plato, 1992).

The concept of basic design education as a means of individual development originates from the groundbreaking early 19th-century theories that emphasized learning through hands-on activities in child education (Whitford, 1984). In the early stages of development, children construct complex shapes by combining simple geometric forms. They arrange these parts with an awareness of their contribution to the overall design, indicating their ability to plan proportions and maintain unity (Arnheim, 1974). This concept can be extended to illustrate how simple elements or ideas evolve into more complex structures. The process of fostering complexity continues as constant elements interact to form a more comprehensive whole.

The methodology of the 'Space' course in Vkhutemas aims to build a pedagogy concerning modern ideas of expressive form and dynamic composition. One of the precursors to the current basic design studio course introduced the geometric study model as a tool for design and teaching. The approach promoted experiential learning, as a result, design education became more accessible. Students often began models without a predefined outcome, learning through the process. Initial designs weren't bound by scale or function, resembling the "laboratory constructions" by notable Vkhutemas professors and Constructivists, including Alexander Rodchenko and Vladimir Tatlin. After understanding the basic principles of spatial form, students progressed to specific design assignments (Bokov, 2018).

In his workshop ‘Slogans’ published in Artistic-Constructive Education during 1920-1921 in the Vkhutemas’s first years, Rodchenko states that art, like other scientific

disciplines, is essentially a type of mathematics, and constructing involves arranging different components in an orderly way (Rodchenko, 1992).

As evidence, recent research supports the strong connection between spatial skills and mathematic performance (McDougal et al., 2023). The role of spatial skills is particularly evident in the relationship between Lego construction capability and math ability. This relationship may vary based on the geometric content and physical or digital type of Lego. Given the findings by McDougal et al. (2023), children who are better at constructing with Lego generally have stronger spatial skills and higher geometric abilities.

In the late 19th and early 20th centuries, the creation of tangible physical models made complex mathematical and scientific concepts more accessible. These models, representing abstract geometric shapes and chemical structures, changed how scientific forms were understood and appreciated. They played a crucial role in teaching and communicating complex geometries. The mathematical models also influenced architecture by directly scaling the models to form a building or using the logic behind the models as a template for architectural design. Two types of these models - string-based models of ruled surfaces and models of differential and topological surfaces - have inspired different formal and computational cultures within architecture (Witt, 2022).

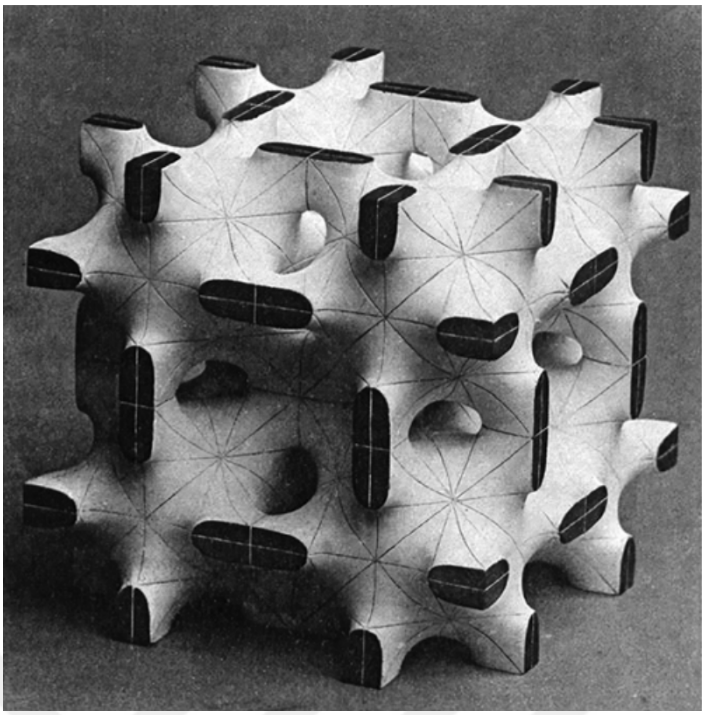


Figure 13 Edvard Neovius's Triply Periodic Minimal-Surface Model (Witt, 2022, as cited in Neovius, 1883).

Figure 13 displays Edvard Neovius's triply periodic minimal-surface model, as Witt (2022) discussed. Neovius's model is among the earliest attempts to explore and physically represent infinitely extensible minimal-surface geometry.

A puzzle is any kind of geometric recreation with pieces (real or imagined) that fall apart and reassemble (Coffin, 2006). Although the geometric recreation term is used, Coffin emphasizes that many valuable geometric puzzles have non-mathematical aspects, and many puzzle ideas come from inventors and craftsmen, not mathematicians. Creative activities that aren't geometric puzzles often involve uniting

discrete parts. Thus, a puzzle inventor could find inspiration in classical arts as much as in mathematical textbooks.

Table 6 *Historically, Building Blocks and Construction Toys*

Type	Name/Description	Date
Building Toy Blocks without Joints	German Anker blocks (The Anchor Stone Building Blocks)	1877
	Froebel's Gifts	1836
	Pratt's modular Unit Block design	1913
	Montessori sensorial materials	1907
	Kapla blocks (117 mm x 23.4 mm x 7.8 mm)	1987
	Keva planks (6.4 mm × 19.1 mm × 114.3 mm)	1997
	Caroline Pratt Unit Blocks	1913
Interlocking Studded Building Bricks	Kiddicraft Self-Locking Building Bricks (patented by Hilary Fisher Page)	1947
	LEGO	1949
	The Toy (designed by Charles and Ray Eames)	1950
	House of Cards (designed by Charles and Ray Eames)	1952
Construction Sets	Meccano	1901
	Erector Set (originally patented by Alfred Carlton Gilbert)	1913
	K'nex	1992
	Fischertechnik	1966
	Tinkertoy	1914
Spaceframes	Zometool (zome as the combination of dome and zonohedron)	1992
	Hoberman sphere (presents an experiment of movement of dynamic and expandable structure)	1995

As illustrated in Table 6, the fundamental building blocks and constructions toys have a long history of use and innovation. Many of the designs mentioned in the table are still in use today.

2.3 CIX, The Topological Construction Toy

Variable alignment and construction techniques have been developed to create geometric structures. Resch (1973) categorizes the generation systems into combinatorial, geometric, and topological. The topological principles are employed in three-dimensional design, game design, and architecture to create structures with continuous surfaces and diverse types of curvature.

The thesis aims to examine the French architect Fabien Vienne's geometric experiments and topologic developments of building blocks. For this purpose, the Vienne's (1996) CIX geometric structure is deployed. The CIX is a game block, also known as the topological construction toy, that has evolved from the topological relationships. In the context of CIX, this is accomplished by repeating a limited number of compatible parts arranged in a virtual cubic space following specific rules. The topological relationships of the CIX are only possible in a physical environment.

2.3.1 Geometry Generation Systems and Topologic Relations

The artist and applied mathematician Resch (1973) describes three generation systems to determine the geometric surfaces of planes and spheres in architecture. The generation systems are generated according to two rules: the selection of the individual pieces and the way they are assembled. Those three assembly methods are illustrated in Table 7.

***Table** 7 Geometry Generation Systems*

Generation System	Description
Combinatorial	It consists of flexible, replicable elements and connectivity rules within specific constraints influenced by the geometry of the parts.
Geometric	It produces a fixed shape with determined parts and develops structures such as geodesic domes and space frames.
Topological	It involves the continuous transformation of a system, maintaining the connectivity rules and components while transforming the geometry of some parts and clusters.

A combinatorial generation system comprises flexible replicable elements and connectivity rules within certain constraints. These constraints can be determined by the geometry of the parts, similar to the letters of the alphabet or some building blocks. On the other hand, the geometric generating systems produce a fixed shape with correspondingly determined parts. The shape-dependent system develops spherical or flat structures such as geodesic domes (transformations of icosahedrons) and space frames with octet trusses (creation with octahedrons and tetrahedrons) (Resch, 1973).

Topology is concerned with the continuous transformation of a system, whereby the connections between its parts are maintained. In a topological generating system, the rule of connectivity and the components set remain unchanged, while the geometry of some parts and clusters is transformed continuously (Resch, 1973).

Topologic Structure

There are various conceptual approaches to topological geometries and relationships. These range from mathematical descriptions to Ron Resch's paper-based topological designs and his views on generative systems, to Piaget's approach within a cognitive

context in psychology, Arnheim's exploration of visual perception in art, and beyond. These principles facilitate the construction of intricate objects such as Mobius strips, Klein bottles, and Boy surfaces, which can be challenging to visualize. As mentioned by Aarseth (2007), the digital environments of Multi-User Dungeons (MUD) also maintain topological accuracy for the connections between rooms, which is vital to ensure a consistent representation of the terrain.

Arnheim (1974) mentions that early drawings often form topological shapes focusing on roundness and closedness rather than precise geometric forms. Piaget (1971) states that early spatial awareness begins with simple topological relationships before evolving into more advanced geometric concepts such as projective or Euclidean geometry. As Gestalt theory describes, understanding the basic spatial relationships in early perception aligns with topological concepts, focusing on fundamental spatial properties rather than rigid shapes or measurements and lacking consistent size and shape.

The primitive perceptual space aligns with foundational topological relationships such as proximity, separation, order, enclosure, and continuity, which are essential for the theoretical reconstruction of space (Piaget, 1971).

1. Proximity: refers to the closeness of elements within the same perceptual field and is crucial in early perception (Gestalt theory).
2. Separation: helps distinguish elements, becoming significant for developing analytical skills.

3. Order: involves arranging elements in a sequence, forming structured perceptions, and aiding in understanding symmetry.
4. Enclosure: involves perceiving an element as surrounded by others, evolving from simple two-dimensional forms to complex three-dimensional understanding.
5. Continuity: describes the perception of uninterrupted spatial fields, developing over time with increasing sensitivity.

Topology also emphasizes connectedness and boundedness rather than distances, angles, straightness, or shapes (ibid).

2.3.2 Fabien Vienne and CIX

The thesis employs the geometric experiments and topological developments of building blocks as conceptualized by the French architect Fabien Vienne. The following chapters analyze and develop the existing physical construction of topological structures in a digital environment.

Throughout his life, Fabien Vienne (1925-2016) designed and produced various innovative projects ranging from urban design, architecture, furniture, toy design and systems design to geometric patterns. He built structural toys and structural systems to understand and play with the limits of geometry. He saw architecture as the analysis of geometry and the space of systems rather than the production of buildings and geometry as a way of understanding and expressing the world and a quest. Many

designs produced or conceived in physical media have not yet been reproduced in digital media.

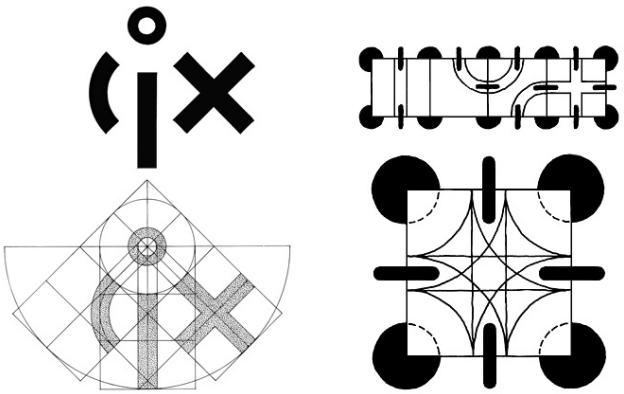


Figure 14 Logo for Building Blok Set CIX (Vienne, 1996).

The CIX game blocks, also known as “the topological construction toy materializes the spatial curvature concept,” were developed by Vienne in 1996 (Figure 14). In the game CIX, players construct a variety of surfaces, including flat and curved ones, by repeating a small number of interlocking pieces.

The pieces, each exhibiting a distinctive curvature and defined thickness, are arranged within a virtual cubic space (Figure 15). The virtual cubic space is an abstract representation defined by a series of cubes of identical dimensions arranged in alignment with each other (Vienne, 1996).

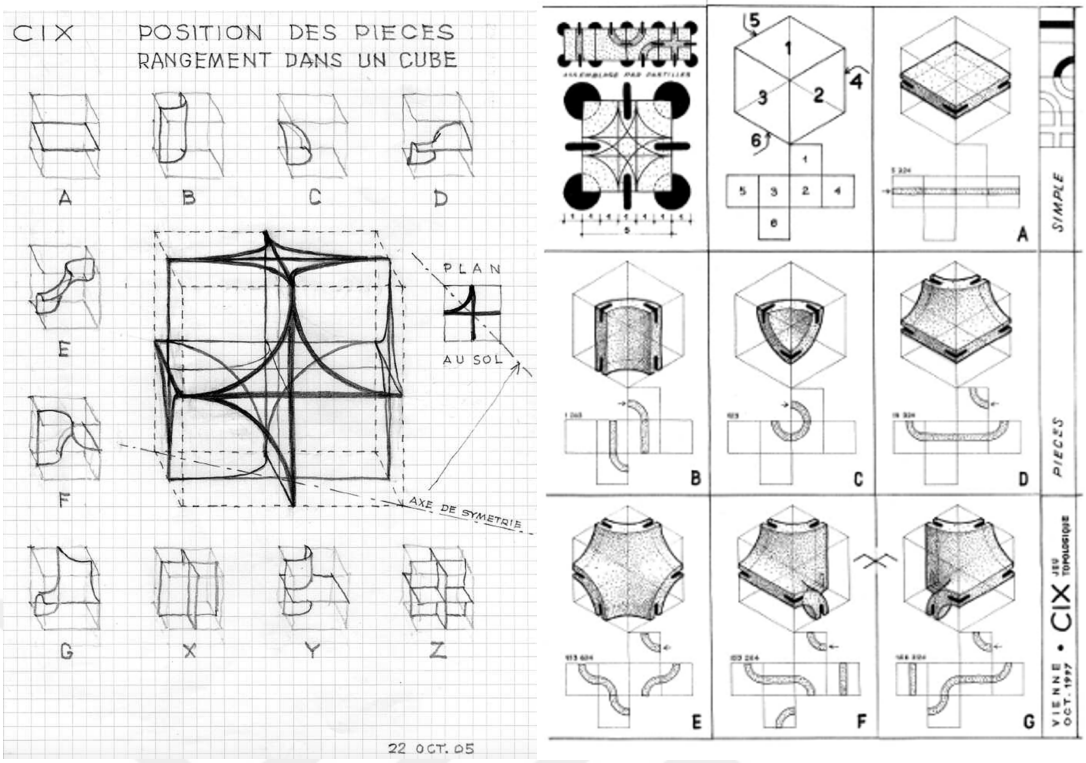


Figure 15 The virtual cubic space and the placement of CIX (From A-G)

The virtual cubic space is subject to certain guidelines, which include the following:

1. Each CIX piece is designed to fit within a cube.
2. The cube's faces serve as connection points between pieces,
3. The thickness of the pieces always intersects the cube edges' midpoints.

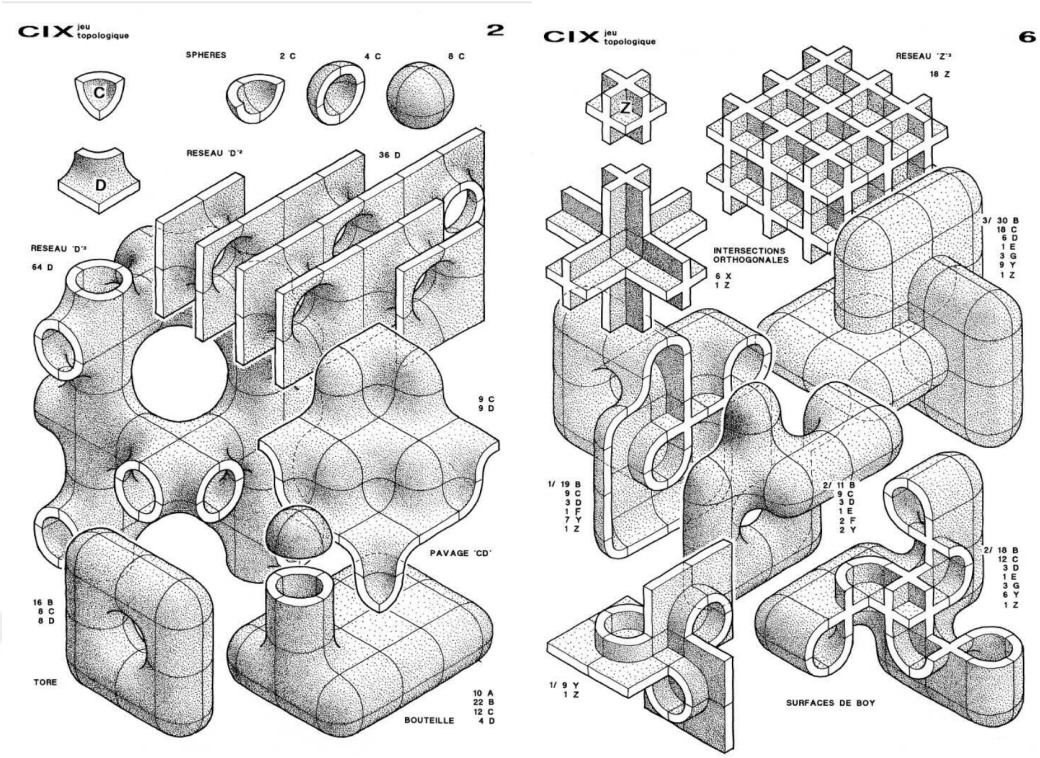


Figure 16 The possibility of CIX topological constructions (Vienne, 1996).

The connection of the virtual grid represents an imaginary three-dimensional grid that is used to establish the topological relationships, as illustrated in Figure 16. As Scotto (2022) observes, Vienne employed the grid as a principal instrument in architectural design, although it is evident that Vienne did not explicitly exploit the grid network for architectural purposes. Instead, he utilized it to create games, geometric structures, and other design elements. More specifically, he employs a three-dimensional grid by establishing a cubic network. Some of his games were created in a cubic virtual network space based on the principle of repetition of a reduced number of compatible pieces.

There are two main types of connections in the arrangements: a quarter-circle connection linking two adjoining edges (Connection C) and a straight-line connection joining two opposite edges (Connection I) (Fabien Vienne, 1996). The other variations evolved from the main curvature connections (Figure 17). The elements are constructed in accordance with the principle of maintaining a connection between compatible pieces through repetition or alteration.

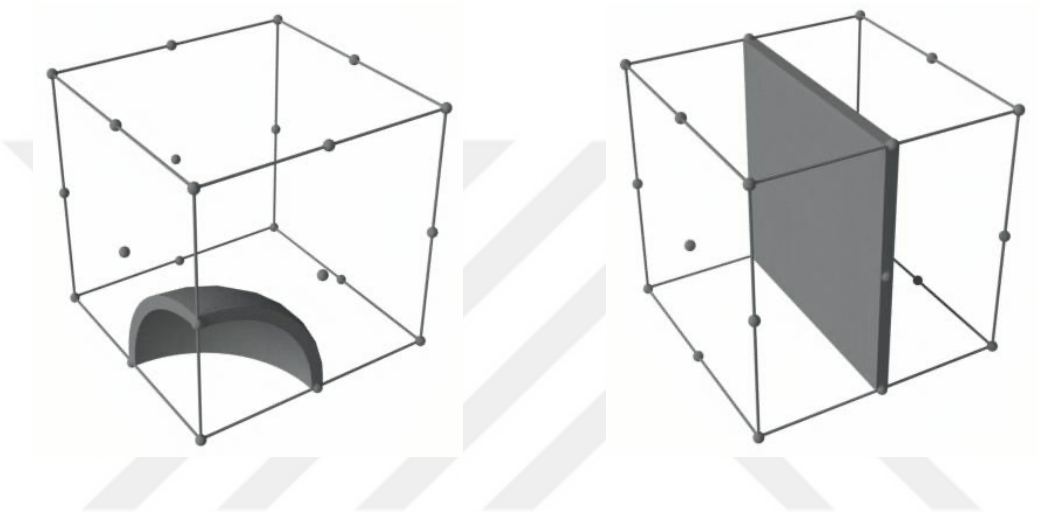


Figure 17 C Connection and I Connection of CIX

The physical pieces of A, B, C, D, E, F, and G are the seven defined shapes based on different curvatures. These shapes facilitate the construction of various open or closed surfaces without overlaps. Vienne outlined a series of 27 pieces in his conceptual drawings, presented alphabetically from A to Z. The CIX elements and their connection parameters are illustrated in Figure 18.

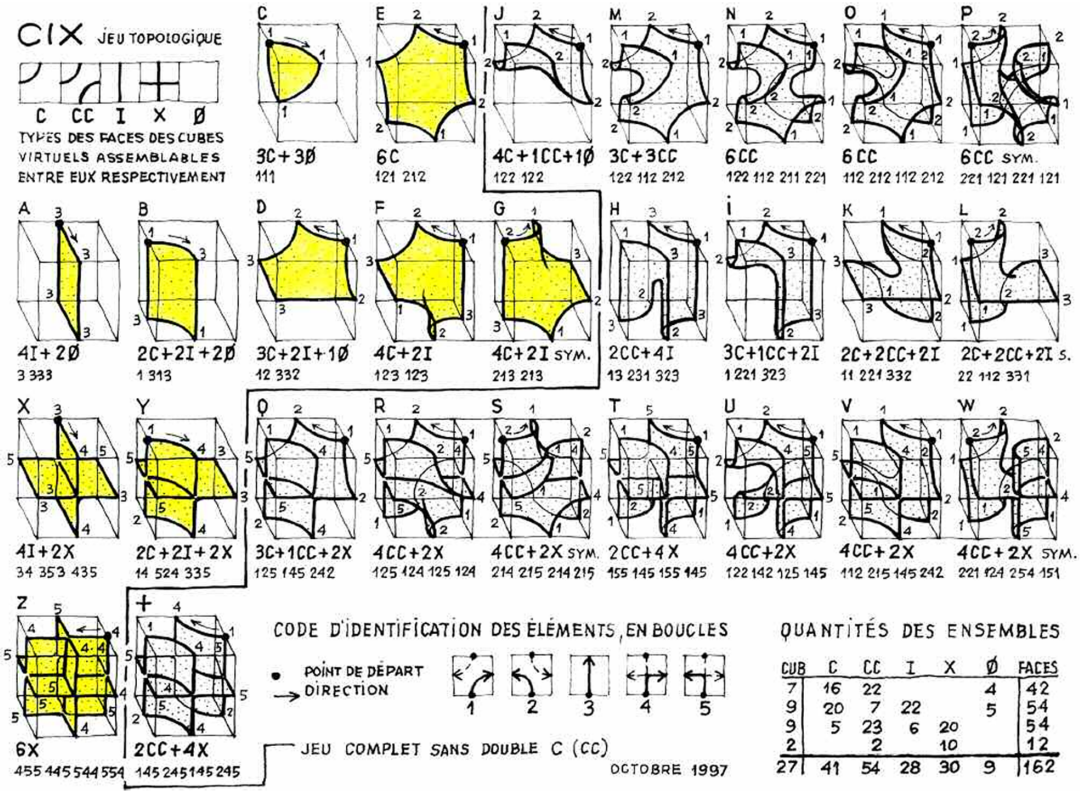


Figure 18 The Elements and Geometric Creation of CIX

Vienne describes CIX in his writings as an uncomplicated yet multifaceted game that stimulates creativity. Vienne mentions that CIX geometric game blocks are suitable for educational studies. CIX offers an effective tool for learning and visualizing different volumes, including planes, cylinders, spheres, tori, and rings. He mentions that any object built with CIX can be dissected along the continuous intersections. Therefore, it can be a supporting tool for the concepts of section, plan, or orthogonal view. Furthermore, it can accommodate the needs of advanced users by enabling the construction of intricate topological entities such as Mobius strips, unilateral surfaces,

Schwarz networks, intersections, Klein bottles, and Boy surfaces, among others (Vienne, 1996).

He states that CIX has broad potential and is well-suited for computerized 3D modeling (Vienne, 1996). However, no research or project has been developed in this context in the literature. In this thesis, the CIX game blocks are reproduced in the digital environment.

2.4 Design Game, GBL, and DGBL in Architecture

In the learning cone by Edgar Dale (1969), there is a noticeable increase in the percentage of preservation of what is learned in the transition from passive learning practices to active and collective participatory models. Iversen and Buur (2002) state that the design processes are dynamic ecosystems where participation plays a central role. It involves communication within the team and with external stakeholders and is strongly affected by the values people share. Donald Schön (1987) describes the design studio as a virtual world that "constructs a representation of the real world of practice." The design practice cannot be considered independently from the social skills, the tension, and the negotiation it causes throughout this process.

Most of the design tools in use have a single-user option. On the other hand, multiplayer and social games foster collective outcomes, actions, and communication. In the case of social game aspects adapted in a design tool, the possible environment allows for collaborative critiques and design processes (Westre, 2013). Lawson (2005)

states that the initial problem of the design studios is that the student's primary focus is on the end products rather than the design process itself.

Creative play, especially in construction and management simulations, often consists of game-like activities rather than traditional gameplay. Creative play allows freeform or constrained play that is limited by the rules (Adams, 2010). Ham (2016) proposes that "Ludenism," which is the ludic practice based on playfulness and a play environment is the basis of the design activity. The ludic practice can be seen as innovative yet rooted in traditional practice philosophy for designers.

2.4.1 Design Game

Design games are increasingly utilized in co-designing processes to involve users and other design collaborators in the initial design stages. Vaajakallio and Mattelmäki (2014) present a framework built on numerous co-design sessions; design games are a playful method to engage co-design partners through game pieces and rules of play. These games encourage people to co-construct potential futures with designers and researchers.

Westre (2013) states that a “design game” isn’t necessarily a game in a traditional sense, despite its name. Essentially, it is a mixture of design tools and digital games. He mentions tools as processes that materialize in software or a device to perform basic tasks. Primarily, the tool extends human capacity to achieve specific tasks. Design games should have simplicity, engagingness, and instrumental parameters that assist

the designer in focusing on one task for a more manageable and functional project. Those attributes distinguished design games as creative and productive tools for design targeting playfulness (Westre, 2013) (Table 8).

Table 8 *The Main Aspect of the Design Game*

Design Games (Westre, 2013; Vaajakallio & Mattelmäki, 2014)	
Aspect	Description
Primary Purpose	Open-ended exploration and creativity within the co-design process
Elements	Points, levels, time limits, randomness
Rules and Constraints	Avoid too restrictive or repetitious rules to allow unlimited outcomes.
Creativity Challenge	Balance of randomness, time constraints, and rules to encourage unpredictable outcomes in co-design sessions
Ideal Environment	Not bound by win/lose, minimal rules, non-repetitive, unlimited outcomes, collaborative environment
Time Limits	Accelerates process; too short may prevent complex results
Challenges	Balancing unpredictability and direction within game constraints.
Outcome	Enhancing creativity, particularly during the conceptual design phase.
Potential Issues	Excessive randomness or loose rules can lead to illogical results or a lack of direction.

However, Habraken and Gross (1988) claim that concept design games are utilized as research instruments to enrich our comprehension of design processes. Rather than serving as design tools or teaching aids, design games are mainly used as research tools. Therefore, he states that design games can facilitate understanding design behaviors, concepts, and complicated subjects.

Westre (2013) states that the primary purpose of a design game is to be open-ended, allowing users to explore a wide range of possibilities. Design games aim for open-ended exploration rather than winning. They should avoid restrictive rules and

repetitiveness. As a result, the ideal design game contains an environment that is not bound by win-or-lose situations, is not overly constrained by rules, avoids repetitiveness, and allows for unlimited outcomes, making the design process more exploratory.

The key challenge is balancing randomness, time constraints, and rules to encourage unpredictable outcomes. Excessive randomness or tight time limits can hinder logical and complex results, while too loose rules can leave the game directionless (Westre, 2013). As a result, design games aim to maintain unpredictability to promote creativity and diverse outcomes. He states that a broad spectrum of possibilities ensures that each session is unique, and this kind of possibility variation reveals creativity, especially during the conceptual phase of design processes (ibid.).

2.4.2 (D)GBL and Architecture

Lye (1995) associates the collective creation process of the first Virtual Design Studio (VDS) (Wojtowicz, 1995) similar to a design game. Digitalized learning environments and searching for new learning methodologies promote game-based learning approaches. Duke (1974) emphasizes that gaming is a form of genuine communication that will be the future language and spread to various disciplines. Lawson (2005) emphasizes the recent phenomenon of the design game techniques in urban design and gradually becoming involved in the architectural design processes. Articulations of the design approaches toward structured play were previously experienced in the design

studios (Feldt, 1972; Green, 1979; Bonta, 1979) and continue prevailing in contemporary design education.

Game-based learning approaches are considered pioneers of the current DGBL approaches. Those approaches affected design studios starting from the 1960s by simulation games adopted from military training (Feldt, 1972; Bonta, 1979). Bonta (1979) asserts an inherent educational value in playing simulation games. This assertion has been repeatedly made in other contexts and is supported by evidence indicating that learners gain knowledge and skills through their active engagement in the learning process. This approach is particularly effective at certain levels of learning and may offer a more effective alternative to learning through lectures or reading alone.

The precedent games developed for architectural design studios possessed diverse objectives such as city planning, solar simulation, landscape, decision-making, construction, and so on. They were designed for different forms of play, including language games, construction, puzzle-solving, and using physical structures like cards, boards, and blocks. The building blocks used to explore the geometric possibilities in various scales for solving a given design problem were a prominent part of the game studies in the architectural design process (Green, 1979; Bonta, 1979). Even though the purpose, method, or scale differed, the common ground for each game study created for the design studios was the collaborative environment of play they constructed.

One of the primary games focusing on urban problems for educational use in the classroom-operated computer environment was first developed by Allan Feldt in 1963 in the name of CLUG (Cornell Land Use Game) at Cornell University (Feldt, 1972). CLUG has established itself as a longstanding and widely applicable game in educational settings to teach urban issues and theories. CLUG aims to provide students with practical, hands-on experience in dealing with urban and regional challenges by giving them a simulated city to manipulate and study. By offering a "laboratory experience," students can experiment with various aspects of a city, enhancing their understanding of urban and regional problems through interactive learning (ibid).

The 33rd issue of the Journal of Architectural Education (1979) has captured the subject of architecture education and game relationships in several articles that can be considered precedent research. The publication presents numerous game-based experiments, each dedicated to a specific aspect of the design process (Bonta, 1979). The Semiotics game was more of a learning tool than a design tool based on discussions between students while playing blocks. While the Awards game, a variant of Semiotics, facilitates a design competition, the Blocks game emphasizes design improvement through feedback to facilitate problem-solving (ibid).

The "cardboard city," a collaborative design approach adapted to architecture studios, was initiated in the late 1970s by students at the University of California, Berkeley, who constructed their own physical living units in groups in urban space. Cardboard City was initially an individual task reflecting real-world situations. Many students

chose to work collaboratively, where teamwork often invites lengthy discussions and power dynamics, offsetting any saved time and resources. Students were tasked with harmonizing their designs with adjacent ones or arriving at a mutual agreement on design language in the area. As a result, the Cardboard City project evolved into a dual exercise, emphasizing collaboration.

Students frequently encounter difficulties perceiving three-dimensional spatial geometry and transferring geometries between two-dimensional and three-dimensional formats. Technological developments integrating digital games and virtual environments with architectural studio environments are designed to address the issues. Coşkun & Çağdaş (2022) emphasized the structural similarity between basic design education and computer games, focusing on the following dimensions (Table 9). The game module offers an effective new interface in basic design education.

Table 9 *Similarities Between Digital Games and Basic Design*

Similarities Between Digital Games and Basic Design (Coşkun & Çağdaş, 2022)				
Targets	Inventory	Interface	Rules	Elements
Points	Interaction	Scenario	Experience	Interaction

Note. Adapted and developed from (Coşkun & Çağdaş, 2022)

Carbonell-Carrera et al. (2021) assert that Minecraft, which involves the construction of 3D shapes within a virtual environment, can effectively enhance and support spatial reasoning abilities. This is accomplished by utilizing visuals and symbols to create and manipulate objects within a three-dimensional space.

Many digital games, including Minecraft, offer a special sandbox mode that supports freeform creative play. Sandbox mode removes the usual constraints and allows the player to do whatever they wish, making the game resemble a tool more than a conventional digital game (Adams, 2010).

In contrast to serious games and those that adhere to a linear narrative, virtual worlds and sandbox games do not impose constraints on players in terms of context. Instead, they afford them the autonomy to shape and control their virtual environments following their imaginations (Bashandy, 2020). Considering student preferences for hands-on activities during the pandemic, Minecraft was chosen as the focus for the online component of the studio's curriculum (Staniewska & Konopacki, 2021).

Game-based approaches in architectural education are increasing both theoretically and within the scope of studio environments due to the involvement of developing technology. Using game-based approaches and technologies in education simplifies difficult problems with its rule-based system and playful environment. Many of them integrate the design process by emphasizing collaboration, autonomy of designing virtually and interactive learning.

CHAPTER 3

COLLABORATIVE VIRTUAL PLAYGROUND IN METAVERSE-BASED ENVIRONMENT

3.1 Collaborative Immersive Virtual Environments

While taking the first steps toward explaining the concept of "cyberspace," Benedik (1991) refers to a parallel universe created and maintained by computers and communication lines and predicts that cyberspaces will have their own rules, functions, characters, and domains. This description is very similar to the metaverse, a phenomenon whose usage area gradually spread over disciplines. The Metaverse is a vast network of 3D virtual worlds that countless users can visit simultaneously. It offers a personal experience with avatars and maintains consistent user data like identity, history, and transactions (Ball, 2022).

Duan et al. (2021) distinguish between two categories of modern metaverse prototypes: Massive Multiplayer Online Video Games (MMO), which are highly interactive 3D game experiences, and Decentralized Virtual Worlds, which are systems driven by blockchain technology. In contrast, this thesis adopts a different

perspective, namely that of a metaverse-based environment. The outcomes of this thesis propose guidelines for a metaverse-based playground in architectural education. Therefore, metaverse-based learning represents an introduction to learning methodology, with future developments to be implemented at a later stage.

3.1.1 Metaverse and Virtual Worlds

As Internet technology has been developed, first in academic settings and subsequently in everyday life, numerous concepts have been proposed in science fiction novels and future imaginations. Two of the key areas of those technologies have been the concepts of cyberspace and the metaverse, which are imagined as inclusive virtual environments.

The concept of cyberspace, first mentioned in William Gibson's novel 'Neuromancer' published in 1984, was first explained by Benedik (1991) as a parallel universe created and maintained by computers and communication lines. He predicted that cyberspaces would have their own rules, functions, characters, and domains; people may have different identities and use cyberspaces for entertainment, learning, personal purposes, or business environments.

The concept of 'metaverse,' included in dictionaries such as Oxford since the 1990s, was first used in the science fiction novel 'Snow Crash' by Neal Stephenson in 1992. The concept of 'metaverse,' which etymologically derives from the Greek word meta, meaning 'after, beyond,' refers to the immersion that goes beyond the physical world,

above all individual and computer-generated ‘universes’ and unites them in layers (Ball, 2022).

In Ball’s comprehensive description (2021), Metaverse is an extensive and interconnected system of real-time 3D virtual worlds and environments. These can be accessed and experienced simultaneously by countless users, each maintaining a personal sense of existence and data continuity. This continuity covers the following areas: identity, elements, history, ownership, payment, and communication. Cheng (2023) outlines six key aspects of the Metaverse: (1) a domain without physical limits, with unlimited accessibility and producibility; (2) continuity, enabling global, anytime connections and collaborations; (3) sensory-engaging realism for inclusivity; (4) network independence for decentralization; (5) an economy powered by blockchain; and (6) virtual relationship networks for social experiences.

Ball (2021) mentions the metaverse as a quasi-heir to the mobile internet, building on the internet and gradually transforming it. Patrick Schumacher (2022) describes the Metaverse as a collection of virtual environments that enable a novel form of interaction through personal avatars over global networks like the internet, with these spaces being interactive 3D or 4D digital models. He argues that the metaverse should be designed as cities created by seamless interactive spaces rather than graphical interfaces of the internet that resemble the pages of a 2D magazine. Accordingly, he asserts that the core competence of building metaverses should be the responsibility of architects in the future.

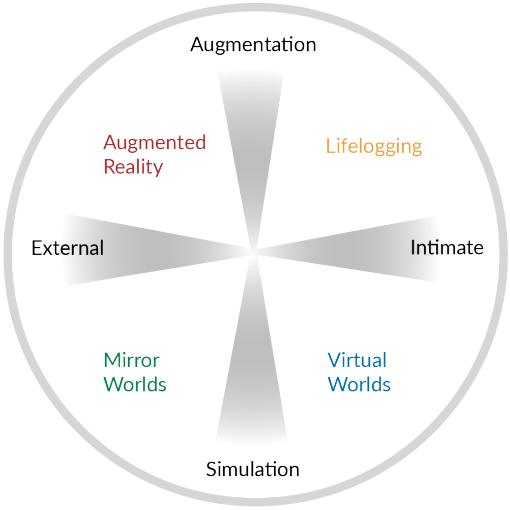


Figure 19 Dimensions of the metaverse based on the 10-year foresight report (Smart et al., 2007)

Smart et al. (2007), in their 10-year foresight report on metaverse and 3D Internet technologies, state that the Metaverse is not merely a virtual space but a conjunction point of our physical and virtual worlds. According to Smart et al. (2007), the future of the metaverse consists of two dimensions, "augmented or simulation" and "external or intimate" at the intersections of the axes; the division occurs into "virtual worlds", "mirror worlds", "lifelogging" and "augmented reality" (Figure 19). Among those axes, Smart et al. (2007) state that virtual worlds are the most discussed topic, and this thesis is also built on the axis of production with virtual identities in the virtual world.

The virtual worlds, which are parts of cyberspace, create new ways of communication and expression with a new perspective. Frazer (1995) mentions that with the emergence of cyberspace, the perception of the known world is reshaped, nourishing the modes of thinking and communication. Cyberspace is not an alternative but an additional dimension for the real world that coexists with and extends it (Frazer, 1995).

Virtual world term does not have clear boundaries in the literature, and it is an umbrella term connecting various digital and collaborative environments. The virtual world is accepted as a main heading covering massively multiplayer online games (MMOG), massively multiplayer online role-playing games (MMORPG), and socially based multi-user virtual environments (MUVE).

MUD (Multi-User Dungeon), developed by Roy Trubshaw in 1978, is considered the precursor of today's virtual worlds and metaverses. It was designed to allow players to interact toward a common goal in the same environment (Bartle, 2004; Downey, 2014). This period marks the prehistory of virtual worlds. As illustrated in Figure 19, the advent of the Internet in the 1980s facilitated the development of text-based interactive games, which laid the foundation for the emergence of multiplayer online environments.

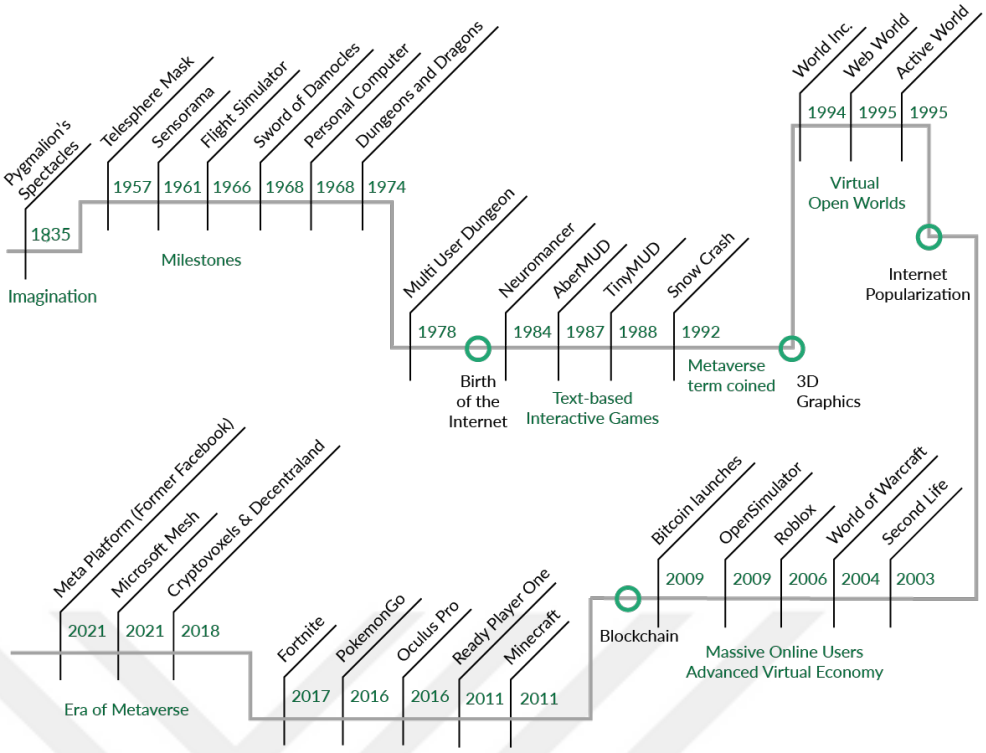


Figure 20 Timeline of the Metaverse Environments (adapted and developed from Duan et al., 2021).

Since the 1990s, with the rapidly developing technology from 2 and 2.5 dimensions to 3D graphics technologies, virtual worlds like Worlds Inc. (1994), Web World (1995), and Active Worlds (1995) have been designed. Active Worlds allows navigating between different virtual universes created by many users (Duan et al., 2021).

Second Life (2003) represents a prevailing world actively engaging in educational activities. It differs from the others in that it allows players to create content and work collaboratively on diverse activities and projects (Downey, 2014). The period also saw the rise of other notable titles, including the massively multiplayer online role-playing game World of Warcraft, released in 2004, which introduced advanced virtual

economy features and attracted a vast online user base. The 2006 launch of Roblox, a user-generated virtual world platform, further expanded the scope for user-created content in virtual environments. In the following years, the release of Minecraft in 2009 contributed to the ongoing evolution of the online gaming and virtual interaction space.

The advent of blockchain technology in 2017 created new possibilities for secure virtual transactions and ownership within these virtual realms. This development occurred concurrently with Cryptovoxels (2018) and Decentraland (2019), blockchain-based virtual environments.

3.1.2 Extended Reality and Immersive Experiences

Ball (2021) states that the metaverse includes Extended Reality (XR) technologies but has a broader scope. The Metaverse is often associated with virtual reality (VR), but VR is just a way of experiencing the Metaverse, not the Metaverse itself. Even without XR devices, millions regularly interact in virtual worlds, spending dozens of hours monthly (Ball, 2021).

XR technologies, including but not limited to augmented, virtual, and mixed realities, can modify our perception of and interactions with the physical and digital domains. In terms of emphasizing human-machine interaction, XR is an umbrella term for augmented reality (AR), virtual reality (VR), and mixed reality (MR). These technologies enable new ways of performing tasks in a world where these domains are

increasingly intertwined. The operation of these technologies is enabled by a complex combination of digital technologies and software, which shape user experiences and provide a foundation for the emergence of a virtual revolution (Greengard, 2019).

According to Fuchs et al. (2011), virtual reality is the simulation of the behaviors of 3D entities in a virtual environment using interfaces and sensor channels that involve one or more users. In AR, the real world is perceived with a digital layer through a device that acts as a "magic lens" (Hughes, 2012). VR offers an immersive experience, and AR provides a supplementary experience. MR on the other hand, is a term used to define a situation in which VR and AR intersect in a physical world (Greengard, 2019).

In Oxford's online dictionary's description, VR is a computer-created, realistic environment that allows interaction through specific hardware like a headset or sensor gloves, serving as a platform for various activities, also known as cyberspace. However, cyberspace and virtual worlds differentiate from virtual reality. Bartle (2004) states that while virtual reality focuses on interaction mechanisms, virtual worlds primarily attract users by the experiences offered upon entry rather than the entry methods.

Virtual reality experiments began in the early 19th century with 360-degree panoramas and optical illusions (Greengard, 2019). In the 1960s, Morton Heilig laid the foundational framework for modern virtual reality with the invention of the Sensorama (Heilig, 1961) (Figure 21). This pioneering invention explored the potential of engaging multiple senses in a simulated environment.

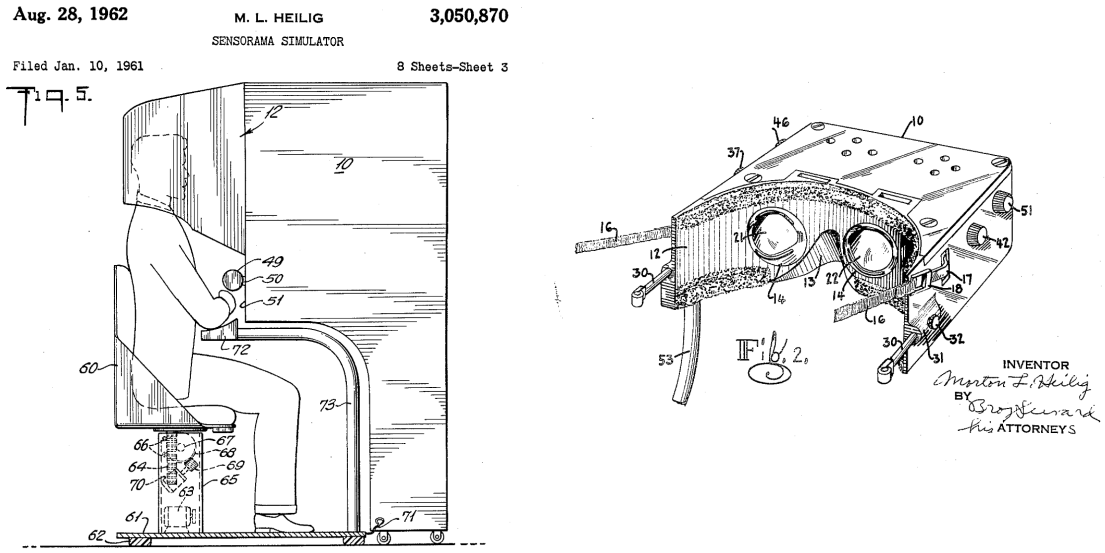


Figure 21 Patented project of Sensorama Simulator (1961) and Telesphere Mask (1957) by Morton Heilig.

The world's first head-mounted display (HDM) was developed by Philco Corporation in 1961. The Philco Headsight system used a remote-controlled video system to display realistic images, tracking the wearer's movements for interaction, which was used in military practice. In 1968, Sutherland created the Sword of Damocles, an early head-mounted display that streamed graphics to glasses and adjusted images based on user movements. It remains one of the predecessors of head-mounted displays of the current extended reality devices (Greengard, 2019) (Figure 22).



Figure 22 The Philco Headsight system from 1961 (on the left) (XR Atlas, n.d.) and the Sword of Damocles by Sutherland in 1968 (on the right) (Greengard, 2019).

Established in 1988, NASA's Virtual Environment Workstation (VIEW) was a cost-effective, portable solution for 360-degree simulations, paving the way for future VR technology. It provided a stereoscopic image aligning with human vision, with advanced wide-angle, auditory, speech, and tactile input technologies. Its uniform interface reduced operator workload and training, increasing productivity and human-machine interaction (Fisher et al., 1988).

In 1992, researchers from the Electronic Visualization Laboratory at the University of Illinois in Chicago introduced the first truly immersive virtual space, the Cave Automatic Virtual Environment (CAVE). CAVE offers a virtual-reality cube-shaped room with projections on all sides, using a head-mounted display and controllers for interaction (Greengard, 2019).

The term "virtual reality" provides users with an immersive and interactive virtual experience with surrounding displays, sound, and body movement tracking sensors (Fuchs et al., 2011). Fuchs et al. (2011) states that the main principles of virtual reality are immersion, interaction, and user inclusion.

Virtual reality can be classified according to the degree of immersion, ranging from non-immersive, where only some senses are stimulated, to fully immersive, where the virtual environment completely replaces the physical world. Fully immersive VR, offering the most realistic experience, requires advanced hardware and software, including a head-mounted display and devices like a haptic glove for interaction, technologies for larger field-of-view and 360-degree mobility (Greengard, 2019; Freina & Ott, 2015).

3.2 Collaborative Virtual Playgrounds for Architecture

According to Huizinga (1980), the play carries its own unique progression and significance. Play initiates, and at a specific point, it concludes. During its course, play is characterized by a continuous state of motion, change, alternation, succession, association, and separation. During its course, play is characterized by continuous motion, change, alternation, succession, association, and separation (ibid). The play activity is the design process within a predefined boundary of time and space. Walz (2010) refers to this space as the playground. In this playground, play creates its form and is shaped by its spatial limitations.

Huizinga states that the playground could take various forms, such as an arena, stage, or card table (1980). These spaces are isolated and protected, and special rules apply to them. Play creates a unique and absolute order within a playground, a space specifically marked out for physical or conceptual play. Any deviation from this established order within the playground spoils the game, stripping it of its character and rendering it meaningless. Thus, play inside the playground demands absolute and supreme order, bringing temporary and limited perfection within an imperfect world.

For Huizinga (1980), the most critical feature of the play is its segregation from real life by its spatiality. Play involves stepping out of "real" life and entering a unique “temporary sphere of activity.” Playgrounds are temporary worlds within the ordinary world, dedicated to a specific activity separate from ordinary life. Aldrich (2009) mentions that all games belong to a virtual world, whether in a physical or virtual construction.

The history of the playground for immersive architectural approaches can be traced back to Cedric Price's attempts. His projects promote social interaction in a computerized architecture, which takes place as if in gameplay. His “virtual architecture” aims to develop a playground for varied activity possibilities for the participants involved.

“The temporary sphere of activity” description expands in today's reality with novel technologies through various interfaces of virtual words, extended reality, and metaverses.

3.2.1 Playgrounds of Immersive Architecture

As Walz (2010) mentions, architecture is not just a passive setting for gameplay but an essential element resulting from a thoughtful and creative process. Cedric Price is an architect known for his unbuilt projects that challenge traditional architecture. His projects reflect ideas from the 1960s on individual liberation and empowerment (Mathews, 2006).

Price's architectural designs were informed by the principles of information flows and cybernetics, which emphasize the feedback and control of systems. Price approached architecture as a serious play with his proposals of responsive buildings. The buildings respond to their users as if in an architectural game that contains rules to reshape the designer and user role (Steenson, 2017).

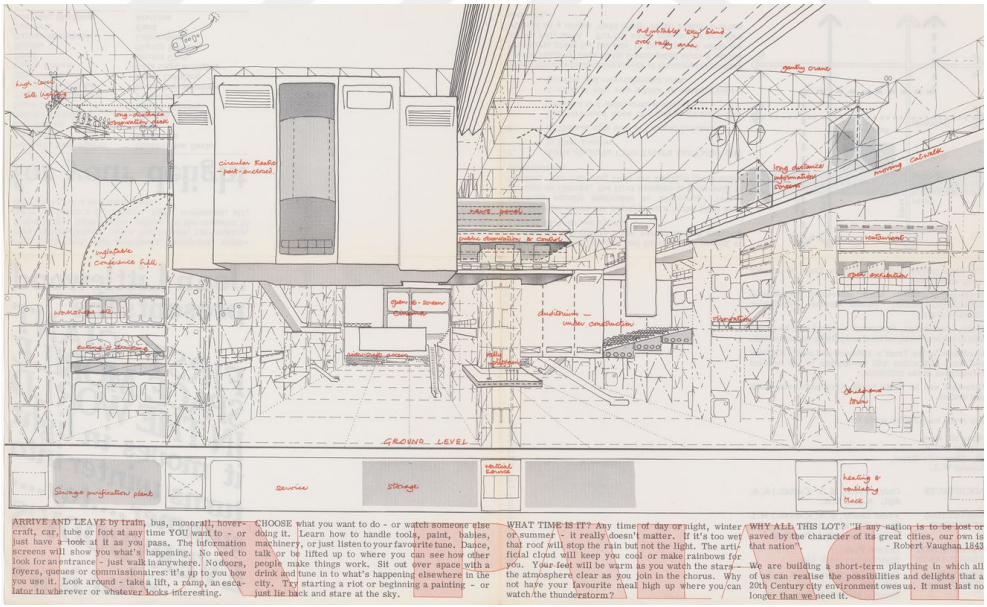


Figure 23 Brochure of Fun Palace by Cedric Price (Canadian Centre for Architecture, 1964).

Price's Fun Palace project combined technology and social interaction to create a unique concept of "virtual architecture." Fun Palace is a dynamic machine comprising cybernetics, game theory, and technology elements. Mathews (2006) states that Fun Palace is a social and interactive structure constantly evolving through dismantling and assembly processes. Fun Palace explored the idea of buildings that learn and respond to users, making them unpredictable and ever-changing. It can be said that it creates a playground by prioritizing social interaction and providing an environment for people to exhibit creativity (Figure 23).

This architectural endeavor can be defined as an "infinite game" that doesn't have a definite end or a specific goal of winning (Carse, 1986). However, Price described his project as a short-term plaything, indicating that the structure's lifespan was envisioned to last only as long as it fulfilled its purpose. Therefore, the architectural game he proposes offers indefinite play within the constraints of its lifespan.

As with Price's Fun Palace architectural experiment, social and interactive virtual environments have been employed in architectural design processes within a design studio setting. The revolutionary approach of creating an unpredictable and ever-changing structure can be adapted to create an experimental playground for education. As the Fun Palace aims to learn from and respond to the users, the thesis promotes that another playground for architectural education can be virtually constructed.

Another imaginative design possibility is conceptualized by Marcos Novak (1991) as a habitat of imagination inside cyberspace with the dematerialization of architectural

space. He argues that cyberspace is a habitat of the imagination, a domain in which the imagination can flourish. This architecture does not follow Euclidean logic and only exists in digital environments and virtual landscapes through the interactions of virtual technologies (ibid).

There are attempts to create a similar approach for a collaborative playground of design education in the literature, which will be utilized in the following section and chapter.

3.2.2 Collaborative Virtual Playgrounds for Architectural Education

Similarly, in the field of architectural education, virtual studios have been innovative practice environments. As time progresses, technological advancements, including computer-aided design practices, extended reality technologies and virtual worlds have become areas of interest for the studios.

Several studies have been conducted to examine the benefits of technologically developed design education. Kharvari & Kaiser (2022) indicate the benefits of using XR technologies in design studies based on the review of the relevant studies. The abbreviated version of the XR usage in an architectural design environment is demonstrated in Figure 24.

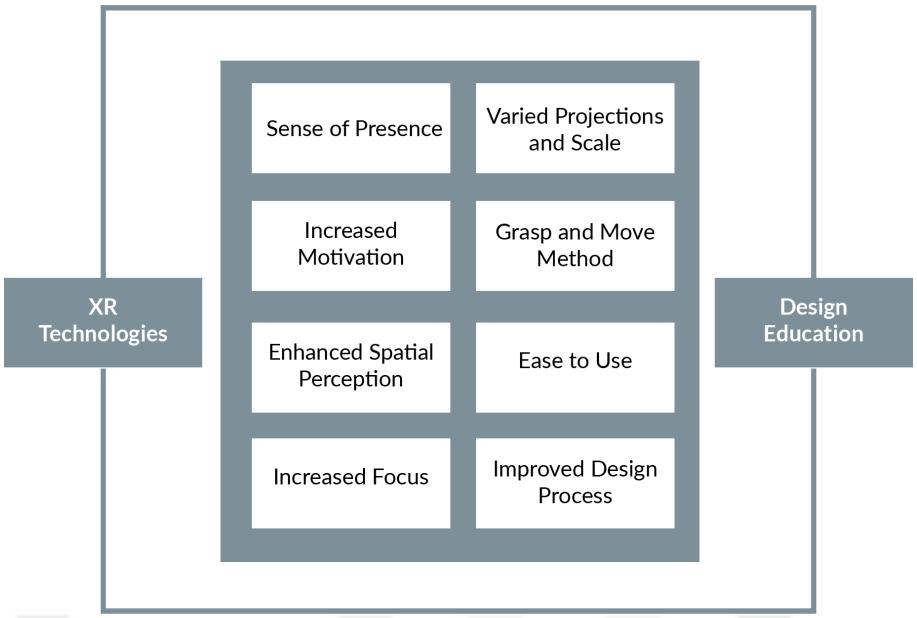


Figure 24 Benefits of XR Technologies in Design Studies

Andia (2002) states that educational institutions have employed computers to be transformed into experimental laboratories to create design tools and broaden the scope of architecture into the digital world and cyberspace.

The first Virtual Design Studio (VDS) (Wojtowicz, 1995) presents that a novel collaboration for architectural design is possible, different from the conventional design studio environment. This endeavor is presented as a new design form of collective imagination with the development of a novel team-based approach to extend the boundaries of design education (Lye, 1995). VDS shows that traditional design studio practices can be adapted to a networked environment, creating a new setting for geographically distributed design practice and education. It ultimately explores how effectively the collaborative and creative aspects of architecture can be conducted remotely (Wojtowicz, 1995).

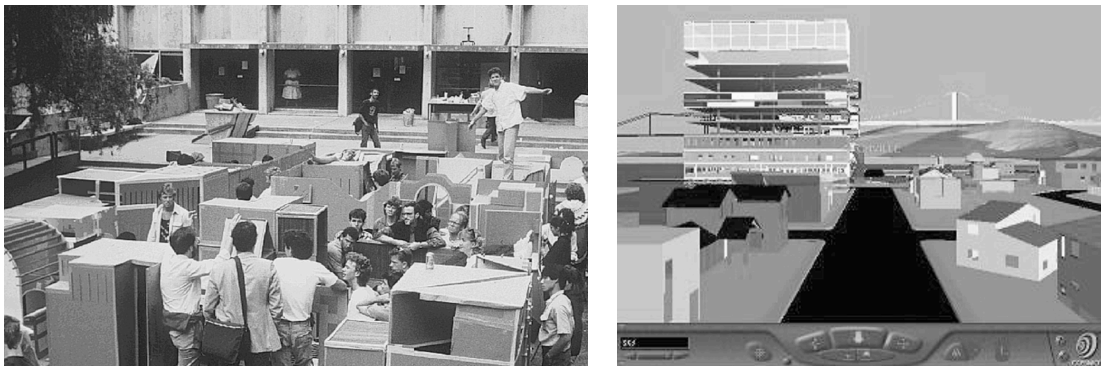


Figure 25 Cardboard City project (on the right); Archville project (on the left) (Kalay and Jeong, 2003).

The late 1970s initiative, “Cardboard City,” continued in the late 1990s with the creation of their real-scale virtual hypothetical city, "Archville," which featured a unique structure and could be navigated (Figure 25). The city allowed participants to interact with their avatars and communicate via chat and email. The game was designed as an adjunct to these early initiatives, which strongly emphasized social and collaborative aspects of architectural design. Archville used VRML to navigate inside the virtual city (Kalay and Jeong, 2003).

Koutsabasis et al. (2012) stated the scarcity of research of computer-generated 3D environments of virtual worlds (VW) focusing on collaborative practice in architectural design process. Vosinakis and Koutsabasis (2013) utilize the OpenSimulator virtual world platform to provide a novel studio workspace with collaborative tools for communication and the design process. A variety of interactive tools were developed within the VW to facilitate collaborative design activities. The researchers indicate that they encountered challenges during the experimental phases,

specifically in the real-time 3D content creation process. Consequently, the workspace utilized pre-constructed elements or building blocks (ibid).

Another example of the utilization of a virtual platform for design experiments is VoxelCO, as proposed by Grasser (2019). VoxelCO is a multiplayer application that facilitates collaborative interaction with the objects, participants, and the environment. VoxelCO offers a virtual playground in the form of a simple game, which allows users to place and remove virtual voxels. The virtual playground is a collaborative environment that is accessible in real time to other participants.

The primary advantage of VoxelCO is its capacity to accommodate groups of 5-20 students per session within a digital playground environment, facilitating continuous communication. In the Voxelstage phase, undergraduate students constructed tangible voxel designs based on the virtual proposals (Grasser, 2019). This is attributable to the inherent limitation of the application, given the necessity for the creation of virtual elements in real space at a human scale. This is due to the fact that VoxelCO is compatible with three different platforms (PC, iOS and Android) within an augmented reality environment. However, the virtual reality environment allows for interaction with different sizes of elements in a human-scale context by avatars. Therefore, a potential development of the collaborative playground, which is the focus of this thesis, could concentrate on the strengths of VoxelCO while learning from its limitations.

CHAPTER 4

DEVELOPMENT AND ASSESSMENT OF "METAVERSE-BASED PLAYGROUND FOR ARCHITECTURAL EDUCATION- MPAD"

The Highly Interactive Virtual Environments (HIVEs) model connects between the distinct characteristics of simulations, games, and virtual worlds (Aldrich, 2009). It presents a unified view of these three interactive environments, highlighting their unique attributes while emphasizing their interconnectedness. This thesis study utilizes this approach by employing a simulation application to create a game experience within a virtual world. The Metaverse-based Playground for Architectural Education (MPAD) is produced from integrating different interaction environments to create a comprehensive learning experience for architectural basic design education.

4.1 The Structure of MPAD

Adams (2010) emphasizes the concept of creative play by the simultaneous presence of two distinct characteristics: constraint and freeformness. Constraint can be

manifested in various forms, including physical, aesthetic, or economic limitations. In contrast, freeform creative play is primarily constrained by the game's inherent possibilities and the device's technological limitations.

MPAD adopts the basic design methodology constructed in Vkhutemas that promotes students' constructing geometric models without a pre-determined result and learning through the process. Like the "laboratory constructions," the initial designs were not bound by scale or function (Bokov, 2018). The main aim is to structure dynamic compositions and expressive forms. Once students understand the basic principles of spatial form, they can progress to specific design tasks.

Play and game theories provide a framework for developing a similar guideline for MPAD. The feedback item from “Elements of Game Theories” has been excluded from the conceptualization of MPAD because the VR environment allows a collaborative design process for the basic design participant team. The involvement of the outer physical environment is not permitted within the exploration process in free creative play.

Table 10 *Structure of MPAD*

Structure of MPAD			
No	Thematic Element	MPAD Element	Description
1	Rule-Based Structure	Gridal Surface Topological Elements and Relationships	MPAD is defined by formal rules based on grid and element relationships that guide the play and learning experience.
2	Free Unstructured Play and Voluntarily Participation	Unstructured Free Design Environment	MPAD allows for adaptability and fluid experiences in an unstructured free design process, freely and voluntarily.
3	Bounded in Time and Space	Limitations of Gridal Ground Virtual Sphere Virtual Reality Workshop Sessions	MPAD occurs within a specific spatial boundary, such as a virtual sphere and VR, creating a separate order. MPAD progresses in workshop sessions.
4	Goal and Outcome	Final Design Outcome	In MPAD, the outcome is a final design that determines the players' status and gives meaning and direction to their actions.
5	Balance of Challenge and Skill	Challenge of Working Collaboratively, VR and Digital Skills Design Abilities	MPAD tries to balance the challenge of working collaboratively and the player's skills, maintaining engagement and interest.
6	Cognitive and Emotional Involvement	Cognitive and Creative Design Process	MPAD engages cognitive and emotional processes, fostering creativity and emotional expression.
7	Movement - Kinesis	360-Degree Mobility in Virtual Reality	MPAD involves movement in virtual space.
8	Dynamic Interaction and Participation	Interactive Virtual Design Environment Interaction Between Players	MPAD involves interactive dynamics between players and the virtual environment.
9	Pleasurable Experience and Intrinsic Motivation	Virtually Design Pleasure	MPAD is expected to be inherently enjoyable and provide pleasure. MPAD is pursued for its intrinsic rewards.
10	Engagement and Immersion	Immersion Virtual Reality by Design Experience	MPAD can be a source of deep engagement and a state of flow where players are completely in the moment.
11	Imaginary	Imaginary Virtual Sphere	MPAD involves players creating an imaginary scenario, often seen as make-believe.

The structure of MPAD is based on a framework and constructs that are developed for play and game elements in line with those as shown in Table 1 and Table 3.

1. An **open-ended** and exploratory approach to design education characterizes MPAD. While formal rules do not define MPAD, it offers participants **a rule-based structure** aiming to follow grid and surface interconnections, thereby guiding the play and learning experience. The grid ground provides a foundational structure for students to explore and construct their designs (Table 1-3).
2. MPAD allows fluid experiences in an **unstructured free** design process. Students can voluntarily engage in the design process without the constraints of a predetermined outcome (Table 1-3).
3. Essentially, the **outcome and goal** of MPAD is the final design which constructed by the collaborative study of the design team (Table 3).
4. MPAD occurs within a specific **spatial boundary**, a virtual sphere. The boundary creates a separate order and context for the design activities. The progression of MPAD is structured through workshop sessions, providing a **time-bound** framework for the design process (Table 1-3).
5. MPAD tries to balance the **challenge** of working collaboratively with the players' skills while maintaining engagement and interest. This balance ensures that participants are continuously **motivated** and can develop design abilities (Table 3).

6. MPAD engages **cognitive and emotional processes**, fostering creativity and emotional expression. The collaborative design process require thoughtful consideration and imaginative thinking (Table 1).
7. MPAD involves movement in virtual space by VR headsets, allowing for virtual and physical **360-degree mobility**. This physical engagement enhances the **immersive** experience and supports dynamic **interaction** between players and within the virtual environment (Table 1).
8. This interaction encourages **collaboration** and communication, making the design process a shared and engaging experience. (Table 3).
9. MPAD is constructed to be **inherently enjoyable** and provide pleasure. The platform is pursued for its **intrinsic rewards**, making the design process fulfilling and enjoyable (Table 1-3).
10. MPAD aims to provide engagement and a **state of flow** where players are completely in the moment of the immersive nature of VR (Table 1).
11. MPAD promotes players creating an imaginary design scenario. This imaginative aspect allows creativity and exploration, as participants can envision structures in a boundless virtual environment (Table 1).

To construct CIX blocks digitally, as in the physical version, MPAD elements follow a similar system based on a virtual cube. The virtual cubic space is subject to certain guidelines, the same first three statements and the rest adjusted in the virtual platform as follows:

1. Each CIX piece is designed to fit into a cube.
2. The faces of the cube serve as connection points between the pieces,
3. The thickness of the pieces always intersects the center points of the cube edges.
4. The cube's midpoints and edges are visible due to understanding the 3D virtual grid system.
5. The elements can be assembled in accordance with the faces of the virtual cube and the geometry of the element adherent to the face.
6. Alternatively, unlimited conjunctions can be performed in the absence of gravity and limitations of the cubes.

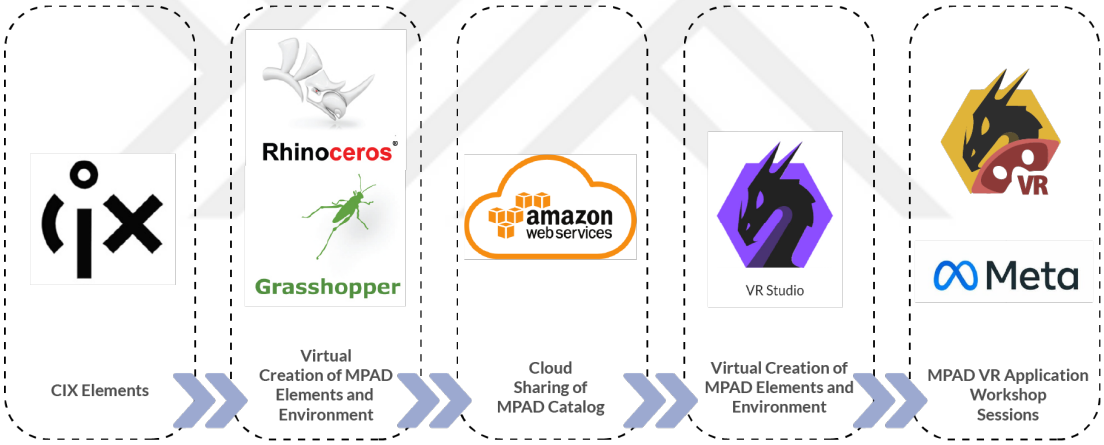


Figure 26 Implementation and Creation Process of MPAD (by author)

The application process of virtual CIX block to MPAD environment involves several key steps utilizing different tools and platforms (Figure 26). It begins with creating CIX elements virtually using Rhino and Grasshopper, which serve as the foundational components (Figure 27). The total number of ten (10) CIX elements are selected for

virtual reproduction, which are described with their alphabetic signs: A, B, C, D, E, F, G, X, Y, Z. The virtual sphere of activity of the MPAD is also created in Rhinoceros, which will be materialized later in the Simlab Soft VR Studio (2023).

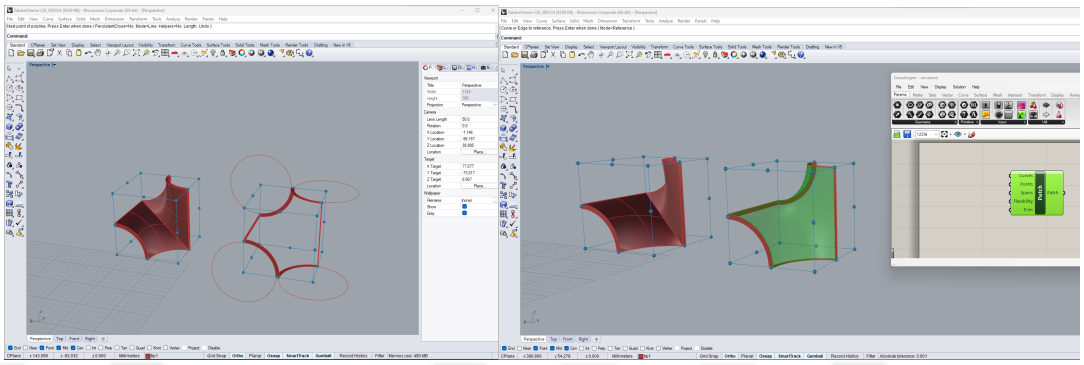


Figure 27 The creation of the virtual CIX elements using Rhinoceros and Grasshopper software (by author).

The interface and design of the MPAD environment are developed using Simlab Soft's simulator software, VR Studio (2023). This software provides the tools to build a simulation environment to generate a game-like virtual world experience. Once the MPAD elements are developed, they are shared via Amazon Web Services (AWS) to create the CIX catalog, which will be accessed in MPAD's interface. The catalog will

be shared with the aid of AWS, enabling cloud-based access and collaboration.

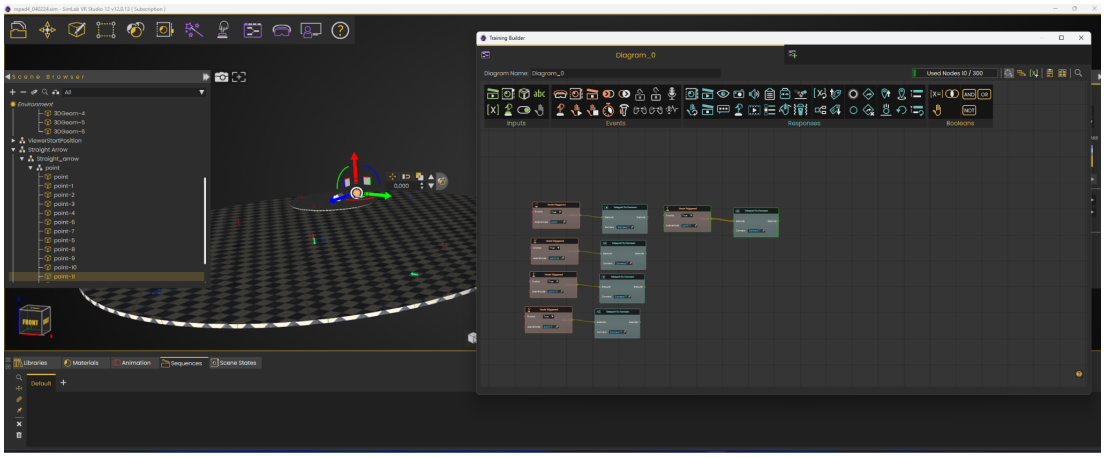


Figure 28 The creation of the interactive virtual environment of MPAD using Training Builder of Simlab Soft's VR Studio (by author).

Further refinement and responses of the interface elements are constructed using Training Builder inside the VR Studio, leveraging the interactive environment to enhance the virtual design experience (Figure 28). In addition to the VR Studio, MPAD project utilizes VR Viewer, designed for viewing and interacting with virtual environments. This software visualizes interactive commands and inputs them in a VR environment. The process concludes with using Meta's VR technology of Oculus Meta Quest 2 and 3, enabling immersive and interactive sessions where users can interact with the virtual CIX blocks in a VR-supported collaborative environment.

The interaction interface of Simlab VR Viewer is implemented for collaborative sessions (SimLab VR Collaboration, 2024). SimLab VR Collaboration, a feature of SimLab VR Viewer, allows multiple users to participate simultaneously in a virtual reality experience. It uses the user's own 3D model as the environment, ensuring

personalized experience. Participants can interact with, trigger, and grab objects similarly to single-user VR experiences. SimLab VR Collaboration is platform-independent and can be accessed via a desktop or a VR headset without hardware limitations. The SimLab VR Viewer enables users to add contacts to facilitate sharing content and invitations to virtual reality collaboration (ibid).

4.2 The Interface of MPAD

The design of the MPAD playground is based on the concept of a "temporary sphere of activity," as described by Huizinga (1980). This concept is utilized to define the boundaries of play, which in turn informs the overall design of the virtual playground. The temporary sphere of MPAD is structured with two virtual playgrounds on top of each other to facilitate different scales (Figure 29).

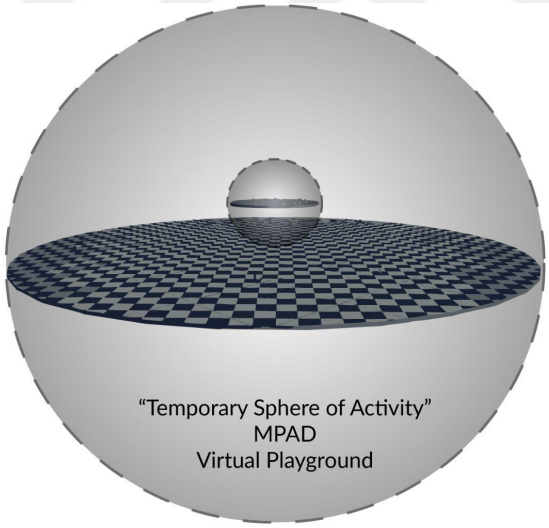


Figure 29 "Temporary Sphere" of MPAD, Two Virtual Playgrounds (by author)

MPAD gameplay aims to provide an immersive virtual reality experience that facilitates an intuitive design process, as illustrated in Figure 30. The MPAD incorporates a comprehensive CIX catalog, which provides access to a range of design elements. The menu interface is designed to be intuitive, allowing easy access to tools and catalogs. The user can manipulate CIX objects using VR controllers, scaling them to varying sizes and rotating them along the X-Y axes. The application offers a scale-copy-delete function, which facilitates rapid modifications and the creation of duplicates. MPAD is equipped with the capability to identify colored objects upon selection. Furthermore, the material section in the menu allows participants to change the texture of the selected items.

The movement of the user within the virtual environment is facilitated by teleportation to different areas of the virtual space. The user is able to interact with the environment through their avatar and observe the avatars of other participants. A virtual-real border of the threshold grid ensures that users are aware of their physical surroundings. This combination of features aims to make the MPAD a basic design tool for virtual projects.

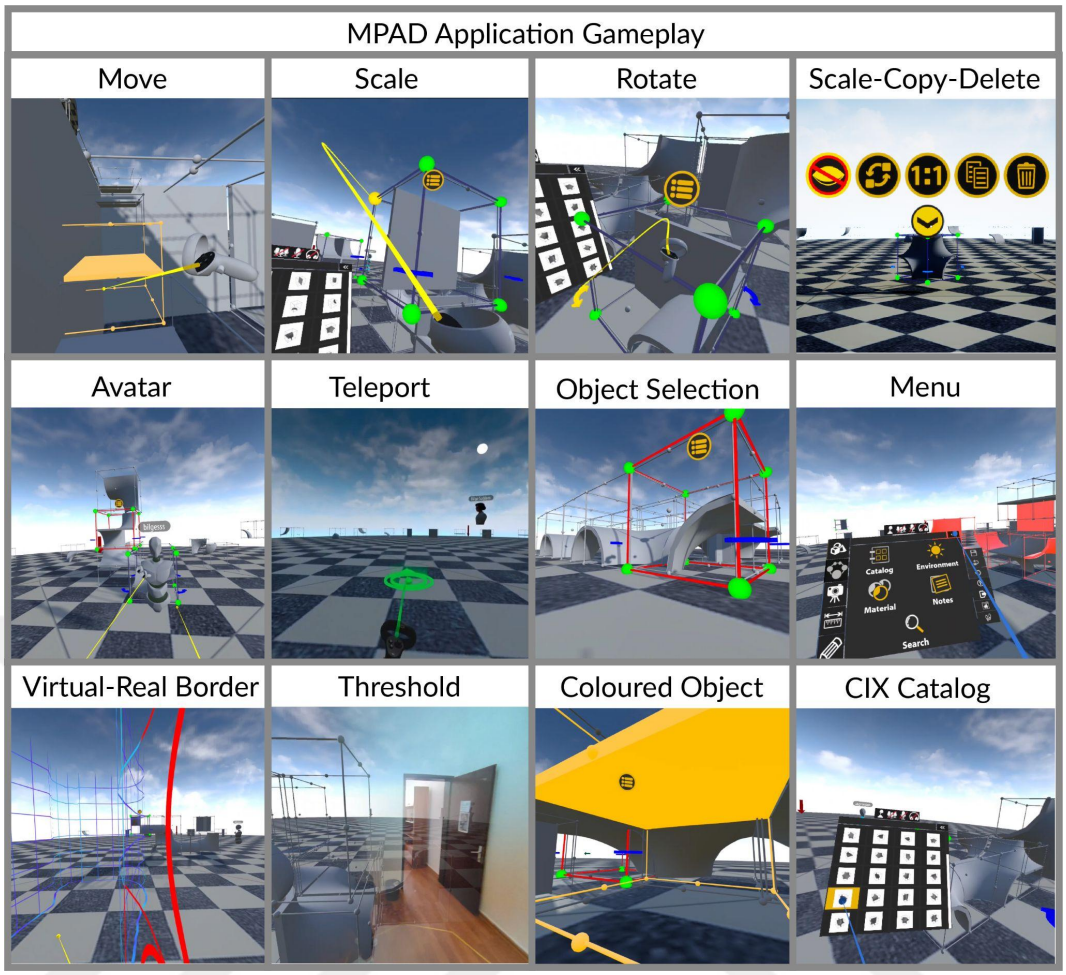


Figure 30 MPAD Application Gameplay

MPAD employs an egocentric reference point to facilitate the integration of a personal perspective with VR headsets. Each player-designer can direct the virtual design by the movement of their body and head, which is guided by their personal position within the environment.

4.3 Data Analysis and Procedure of MPAD

As Aldrich (2009) notes, all highly interactive virtual environments (HIVEs), which connect simulations, games, and virtual worlds, require introductory levels for students

containing basic tasks before progressing to the actual exercises. This concept is similar to video games, where players must complete individual training stages before participating in multiplayer groups. In this thesis, the MPAD is introduced to the participants through a pilot and a main study. The studies are conducted in a virtual reality laboratory and design studios. Before each session, participants are provided with an explanatory introduction video and demonstration (Figure 31).

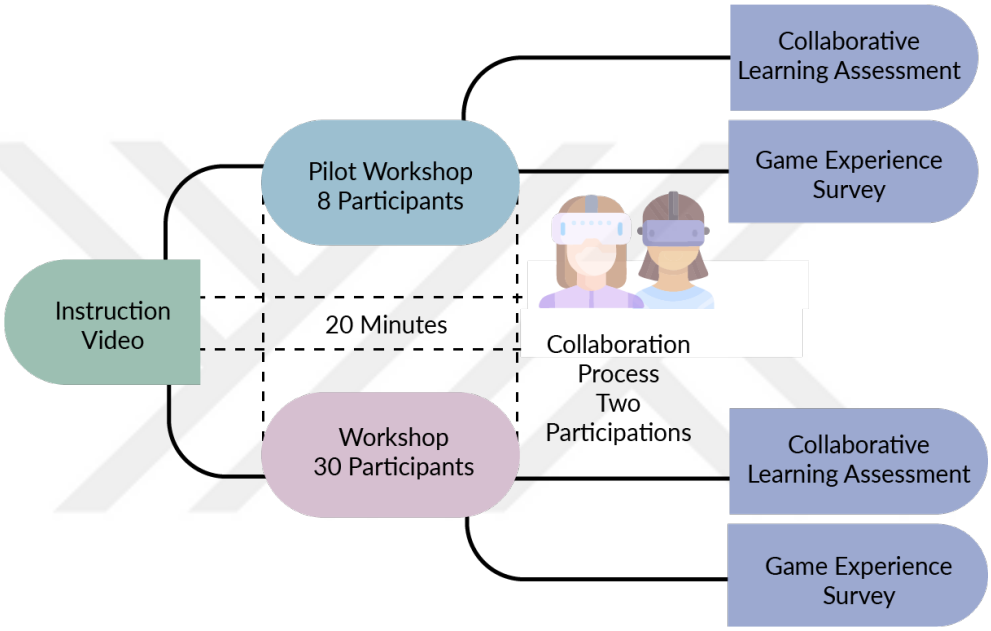


Figure 31 Workshop experiment processes

In similar research, limited samples have been used to assess VR-based design tools, interactive virtual environments, and game-based applications in architecture. Pamungkas et al. (2018) worked with a sample of 50 people, each of whom is a 2nd-year architecture student, while a sample of 32 2nd-year architecture students was used to measure the Gravity Sketch application by Darwish et al. (2023). Goli et al. (2022)

assessed GaoDe, a platform they developed through game-based learning, with 41 first-year architecture students. De Klerk et al. (2019) worked with 18 students aged 20-29 and 5 professional architects to assess Maquetteer, a VR-based model development tool they developed. Özgen et al. (2021) worked with 20 first-year interior architecture students to compare the use of VR technologies in the basic design studio with traditional design methods. In this thesis, total of 38 Basic Design students participated in the study: 8 in the pilot study and 20 in the main study (Figure 31).

The pilot workshop was conducted at Bilkent University, involving 8 Basic Design students, aimed to test and refine the process, which involved using VR headsets in collaborative sessions with two participants, as depicted in Figure 31. The insights from the pilot study informed the larger main study, ensuring the proper application of the cloud-based collaborative sessions with VR headsets. Following the pilot, the main workshop was conducted with 30 students from Bilkent University and Ostim Technical University, who engaged in similar collaborative sessions and completed the same assessments. After collaborative sessions, the participants completed two assessments: a Collaborative Learning Assessment to evaluate the effectiveness of their collaboration and a Game Experience Survey to gather feedback on their experience.

4.3.1 Demographics and Experiment Procedure

In the demographic part of the experiment, the participants answered familiarity questions concerning VR tools, Metaverse, computer programs, and computer design

program experiences. The responses to the statements below are later analyzed for statistical relevance with the variables in the pilot and main study surveys.

1. "Have you ever used tools in a VR environment?"
2. “How often do you use computer programs?”
3. “Have you ever used computer design software for an architecture class?”
4. “Have you ever experienced a Metaverse environment?”

The pilot and main studies took place at Bilkent University and Ostim Technical University, as illustrated in Table 11. The MPAD sessions comprised first-grade students taking Basic Design courses during the 2023-2024 Spring term.

Table 11 *Pilot and Main Studies*

Pilot and Main Studies		
	Bilkent University	Ostim Technical University
Dates	14-22 March, 5-19 April	6-7-9-14 May
Duration	20 minutes	20 minutes
Number of participants	14	24
Places	VR Lab, Design Studio	Meeting Room, Design Studio
Participation	Voluntarily: In accordance with the workshop call, the group members elected to participate for the hours they had selected collectively.	Voluntarily: In accordance with the Basic Design II studio, the group members elected to participate for the hours they had selected collectively.
Demographics	1st Grade Undergraduate Architecture Students	1st Grade Undergraduate Interior Architecture and Environmental Design Students
Number of Participants of Collaborative Sessions	Two	Two

It should be highlighted that at Bilkent University, basic design courses are conducted within an integrated and multidisciplinary framework that brings together students from various academic fields, comprising Architecture, Landscape Architecture and Urban Design and Interior Architecture and Environmental Design.

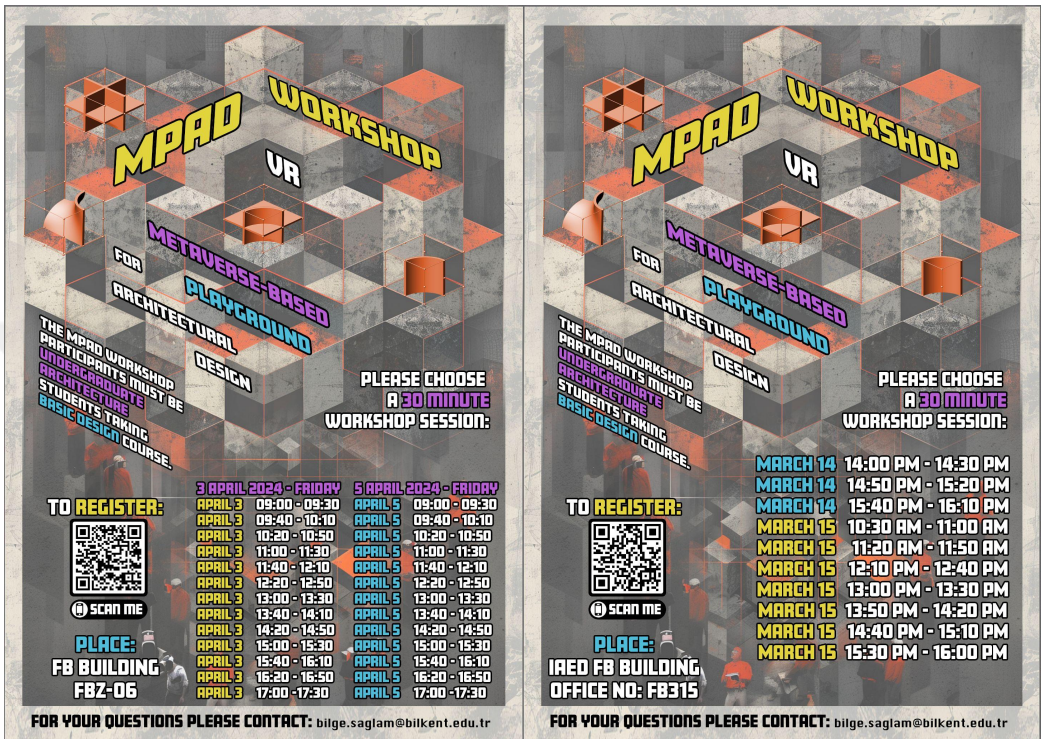


Figure 32 MPAD Experiment Posters in Bilkent University (by author).

The MPAD workshops are conducted at Bilkent University as a series of workshops. The two workshop posters are demonstrated in Figure 32. At Ostim Technical University, the sessions were applied to students enrolled in the Interior Design and Architecture program taking ICM 112 Basic Design Studio II. The MPAD applications were held at the end of the studio courses at Ostim Technical University. Participation in both universities was voluntary.



Figure 33 MPAD Workshop Process; Ostim Technical University (on the left), and Bilkent University (on the right)

4.3.2 Participant Reviews

A total of 22 participant reviews were collected during the workshop sessions and subsequent to the implementation phase. Table 12 presents a summary of the feedback provided by participants regarding various aspects of their experience with a project or tool, both during and after each session. The reviews and suggestions are categorized into seven headlines as follows:

(1) Imagination - Adaptation -Design; (2) MPAD Interaction and Movement; (3) MPAD Environment; (4) Collaboration; (5) MPAD Elements; (6) MPAD Controls; (7) Future Predictions

Table 12 *The Reviews During and After the Sessions from the Participants – Part 1*

Reviews from the Participants (During and After Each Session) – Part 1		
Imagination Adaptation Design	Imagination	- "My problem is that I cannot imagine. I understand my project by entering into it, I perceive it by walking in it."
		- "It can be very difficult to imagine 2 dimensions in the 3rd dimension."
	Learning Curve	- "It can be a 2nd session, the first session is for learning to use and the 2nd session is for design."*
		- "It becomes much easier as we progressed and tried different variations."
		- "While I was spending time learning the game, the design was interrupted."
	Duration	- "Duration could be longer."
		- "It can be a 2nd session, the first session is for learning to use and the 2nd session is for design."*
MPAD Interaction and Movement	Interaction	- "I understand my project by entering into it, I perceive it by walking in it."*
	Movement In MPAD	- "It would be very good if it was possible to fly in the VR and climb on objects."
		- "It can be a good idea moving by flying and seeing surrounding in the air."
MPAD Environment	MPAD Environment	- "The atmosphere was very understandable."
	VR-PC Comparison	- "VR is much easier to use than computer."
Collaboration	Larger Teams	- "When 4-5 people enter at the same time, it can be a lot of fun and different designs can emerge."
	Collaboration Issues	- "I have encountered challenges in collaborative design process. Therefore in the beginning, I started working alone."
		- "We had difficulty in getting along, especially in the collaboration process."
MPAD Elements	MPAD Element Catalog	- "It is challenging to identify the elements from the list"
		- "There may be more elements."
		- "It would be good if there were more elements, for example, if intermediate elements such as stairs and seats were included."
	MPAD Element Shapes	- "Aren't there any diagonal triangular shapes?"
	Shape Manipulation	- "It may be a good idea to be able to manipulate the shapes. I wanted to be able to stretch or distort the elements."

Table 13 *The Reviews During and After the Sessions from the Participants - Part 2*

Reviews from the Participants (During and After Each Session) – Part 1		
MPAD Controls	Object Snapping	- "I struggled a little bit because the elements could not be fully joined, it would be good if they could come and stick together."
		- "It would be nice if the elements stuck together exactly like snapping."
		- "We had difficulties in assembling some of the elements."
		- "It would be good if the elements were joined right next to each other, like a magnet."
	Multiple Transform	- "The multiple selection would be good, for multiple copying."
Future Prediction	Implementation to Studio Schedule	- "If there was such a method for 1st graders, everyone would understand and pass the course much easier and with better grades."
	Future Implementation	- "In the future, it may be necessary to visit and see the projects in this way before they are built, and this will be a necessity."
		- "It would be very good to design by going into the real-life area where we will design, going in the area we want and connecting while we are in that area completely changes the way we design. It would help me correct many mistakes I have made in projects so far. This can change the design process a lot."
		- "In the future, it would be very nice to connect to group projects from home."

Some of the participants had suggestion for MPAD as follows:

- Adaptation Needs: It was stated that multiple sessions may be beneficial, with the initial phase concentrating on familiarizing the tool and the latter phase focusing on the design itself.
- Movement: It was recommended that the software be enhanced to allow users to fly and climb objects in VR, thus improving the user experience.
- Larger Groups: The addition of more team members (four to five individuals) may facilitate a more enjoyable design process, leading to the generation of a broader range of design options.

- Snapping Option: The participants proposed the inclusion of a snapping feature to facilitate the assembly process.
- Multiple Transform: The ability to select and copy multiple elements at once was suggested as a helpful feature.

Some of the participants criticized MPAD as follows:

- Interrupted Design: The time spent learning the tool interrupted the design process.
- Duration: The current sessions do not allow sufficient time for the completed design. The duration of the sessions could be extended to allow for more effective learning and design.
- Collaboration Challenges: The participants experienced difficulties when attempting to engage in collaborative design activities, often preferring to work independently at the initial stages due to the challenges they encountered in communicating and working with others.
- Catalog: Identifying elements from the catalog was a challenging process. Participants requested the inclusion of additional elements, including intermediate ones such as stairs and seating.
- Additional Shapes: Participants noted the absence of certain shapes like diagonal triangles.
- Shape Manipulation: A desire was expressed for manipulating shapes, including the ability to stretch or distort them.

- Object Snapping: Participants struggled with elements not joining fully and suggested a snapping feature to make assembly easier.

Some of the participants positively evaluated as follows:

- Challenges with Visualization: The participants encountered difficulties envisioning two-dimensional designs in three-dimensional space. However, as participants progressed, the design process became easier.
- Comprehension: The participants indicated that their comprehension of the project increased due to immersing themselves in it and perceiving it from within.
- Comprehension: The environment established by MPAD was regarded as highly comprehensible.
- Easy to Use: The participants perceived the virtual reality technology to be more intuitive and easier to use than a computer.
- PC vs VR: A supplementary review was conducted with participant 1 and 2 in a computer-based environment following the MPAD sessions. They observed that the VR environment and controls were more user-friendly and intuitive than the keyboard and mouse controls.

Participants provided future predictions as follows:

- Studio Schedule Implementation: Participants believed implementing such methods for first-year students would enhance understanding and improve grades.

- Construction with VR: It would be advantageous to have the opportunity to view projects in virtual reality before construction begins.
- Virtual-Real Connection: The ability to design in real-life areas and connect to group projects from home has the potential to be a revolutionary step forward in the design process.

The participants provided comprehensive feedback on the various aspects of their MPAD experience, emphasizing both the advantages and the challenges. Furthermore, they expressed optimism regarding the prospective applications of similar tools in educational and professional contexts.

4.3.3 Products of the MPAD Workshop

In the MPAD workshop sessions held at Bilkent University and Ostim Technical University, the participating students engaged in collaborative studies to explore a range of unique design strategies. These sessions were structured into pilot and main studies, with different groups of two and a variety of strategies, resulting in a diverse array of outcomes as illustrated in Figure 34 and 35.

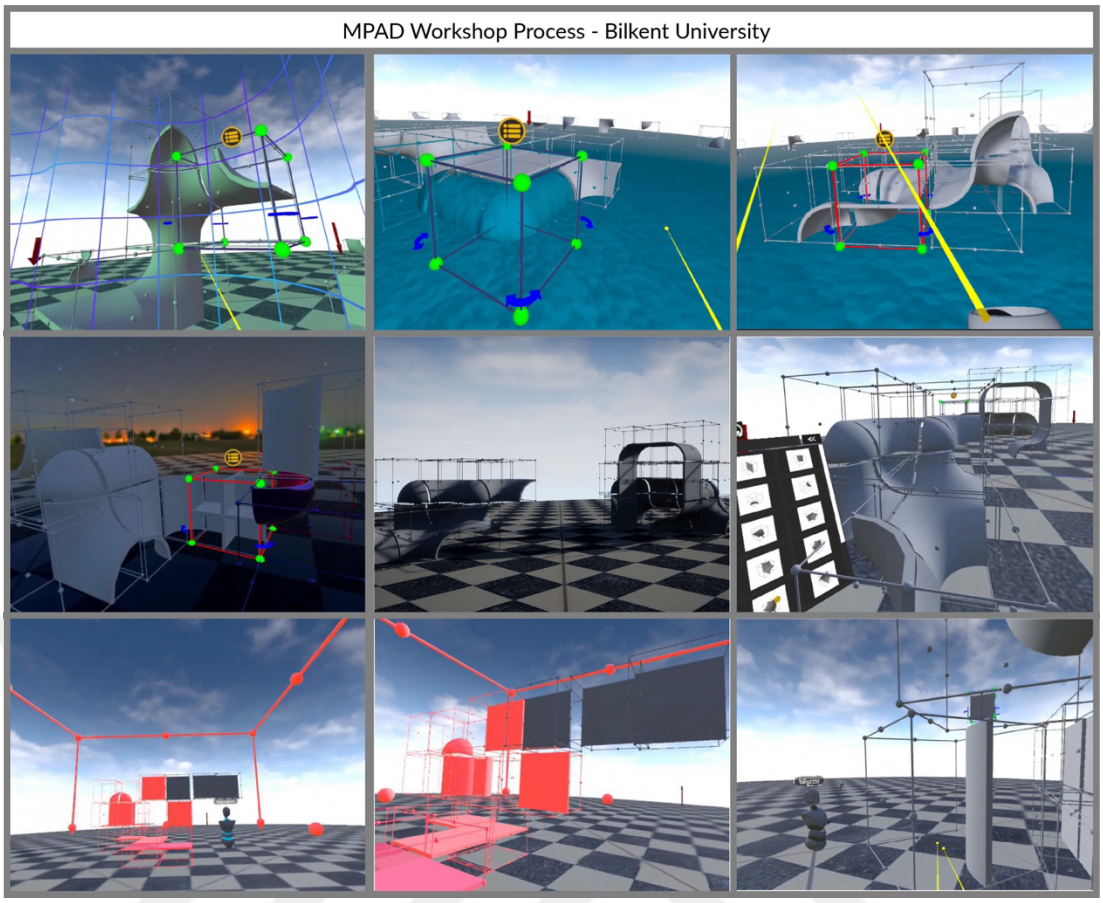


Figure 34 MPAD Workshop Participant Products in Bilkent University

The MPAD workshop at Bilkent University was conducted between 14-22 March and 5-19 April 2024 with a total of 14 first-year undergraduate architecture students.

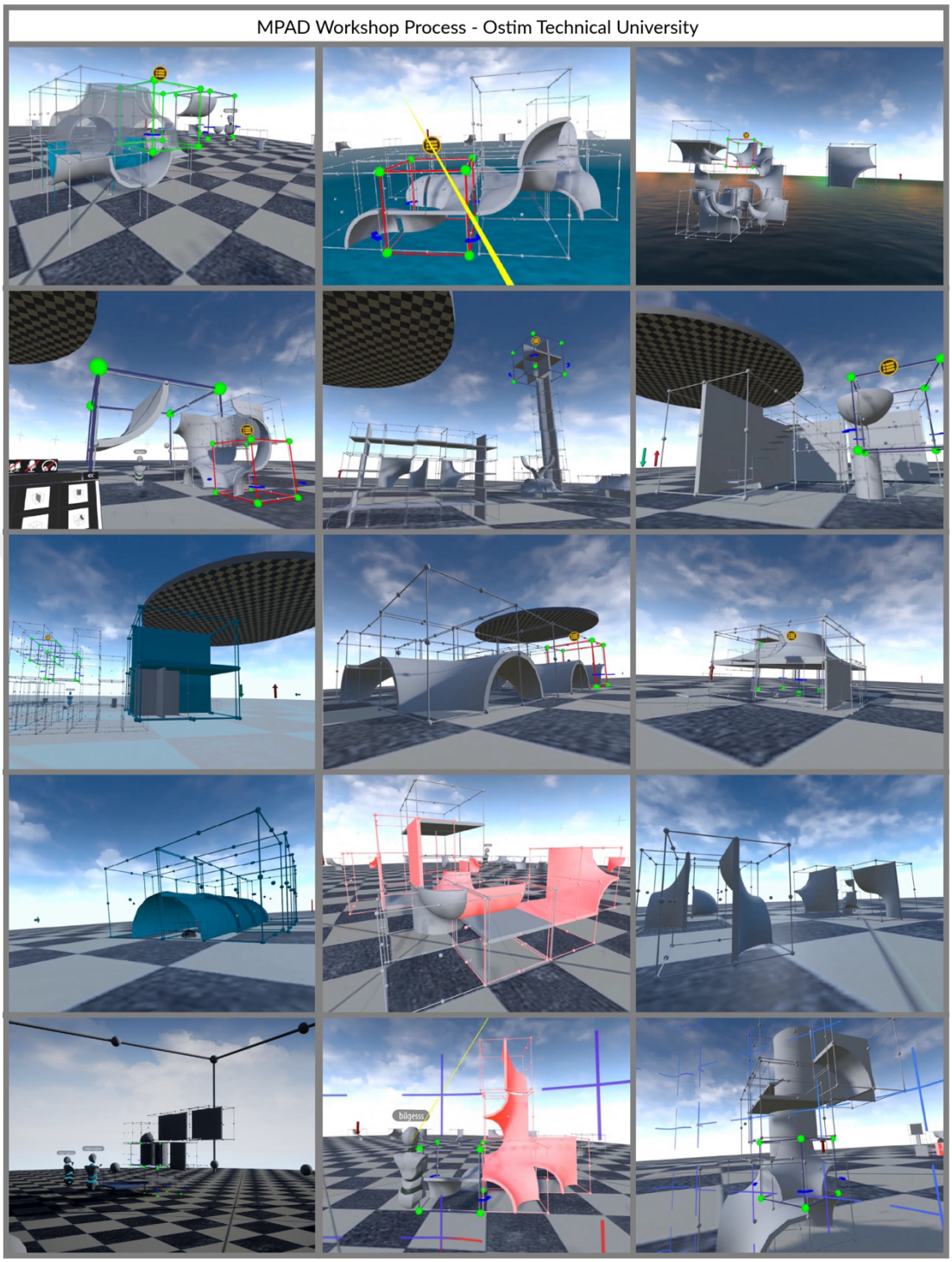


Figure 35 MPAD Workshop Participant Products 2

These sessions at Bilkent University lasted 30 minutes each and took place in the VR Lab and a design studio (Figure 34).

MPAD workshop was conducted by Ostim Technical University on 6-7-9 and 14 May 2024. The participants were 24 students enrolled in the first-year undergraduate program in Interior Architecture and Environmental Design. The 30-minute sessions were conducted in the meeting room and a design studio, in accordance with the Basic Design II studio curriculum (Figure 35).

The products of the MPAD workshop demonstrated notable variation, reflecting the diverse strategies employed by the workshop teams of two participants. Half of the groups conducted experiments involving alterations to the materials used for the elements or the playground itself. This approach resulted in the creation of innovative textures and sensory experiences. Another strategy employed by the workshop teams was the manipulation of scale. This involved playing with proportions of CIX elements in MPAD in order to create unique spatial experiences.

The decision between one of the two grounds in the temporary sphere of MPAD had a significant impact on the grid scale. The selection of the scale was significant in the workshop's design processes. The virtual playground served as an ideal canvas for experimentation, allowing students to push the boundaries of the CIX elements connection to generate unique collaborative results.

4.4 Experimental Process and Statistical Analyses

The statistical analyses of MPAD are comprised of different steps. In the initial phase before MPAD application, the participants conducted the demographic survey comprising the following questions:

- "Have you ever used tools in a VR environment?"
- "How often do you use computer programs?"
- "Have you ever used computer design software for an architecture class?"
- "Have you ever experienced a Metaverse environment?"

After applying MPAD, the post-survey phase is implemented in the pilot and main studies. The Collaborative Learning Assessment scale devised by Muñoz -Carril et al. (2021) is employed, integrating elements from the Technology Acceptance Model (TAM), Expectancy-Confirmation Theory (ECT), and Flow Theory. This scale served as an instrument to assess collaborative learning within the context of MPAD.

Reliability is the critical measure of standardized questionnaire quality. Reliability analysis is crucial for assessing the internal consistency of the instruments. Reliability, commonly assessed using Cronbach's alpha, measures consistency ranging from 0 to 1; a score between 0.7 and 0.8 is generally acceptable for research evaluations (Sauro & Lewis, 2012b).

It is estimated that the values in the Collaborative Learning Assessment are adequate for both reliability. The Cronbach's alpha coefficient for the factors with individual

item reliability is 0.882, and the total mean scale mean is 0.82, above the acceptable threshold of 0.7. This indicates a strong internal consistency, as the variables show a notable correlation within their respective groups.

A descriptive analysis of the Collaborative Learning Assessment is first conducted, followed by the application of a correlation matrix analysis to identify significant relationships among the variables. Moreover, a non-parametric analysis, employing Fisher's Exact Test, is used to assess the correlations between demographic questions and statements about collaborative learning.

Fisher's Exact Test is a nonparametric statistical method to compare observed group counts with expected chance outcomes. Fisher's Exact Test is particularly preferred for small sample sizes. It necessitates using a 2x2 table and calculates p-values by exploring probabilities of all potential 2x2 table combinations with identical marginal totals. The threshold for significance in a two-tailed p-value is 0.05 (Sauro & Lewis, 2012a).

At the end of the MPAD sessions in pilot and main experiments, the second post-survey of game experience adapted from Martin-Dorta et al. (2014) was conducted. The descriptive analysis is conducted for the survey due to each statement reflects a different aspect of the MPAD experience.

4.4.1 The Collaborative Learning Assessment: TAM, ECM and Flow Theory Model

After the workshop experiments, participants completed the Collaborative Learning Assessment. This scale, adapted from the Technology Acceptance Model (TAM), Expectancy-Confirmation Theory (ECM), and Flow Theory, was developed by Muñoz-Carril et al. (2021).

The Technology Acceptance Model (TAM), proposed in 1986 by Fred Davis, is an evolution of the Theory of Reasoned Action (TRA) model. The TRA model was originally designed to elucidate the psychological motivations behind people's behaviors. Over time, the TAM has been refined and adapted to accommodate diverse concepts and research contexts, thereby establishing itself as an extensive tool for understanding user acceptance and usage behavior in various fields (Davis, 1986).

The Expectation-Confirmation Model (ECM), originally proposed by Oliver (1980), is a widely recognized theoretical framework in the field of marketing. The model is specifically designed to measure the impact of consumer expectations and their subsequent perceptions on overall consumer satisfaction. The model provides a comprehensive approach that bridges the gap between consumers' initial expectations and their post-purchase perceptions, thereby measuring the level of satisfaction derived from a product or service.

Csikszentmihalyi's (1977) Flow Theory, a seminal work in positive psychology, is based on the concept of autotelic action. Autotelic is derived from the Greek words 'auto,' meaning self, and 'telos,' meaning goal. In essence, the theory seeks to understand the factors that drive intrinsic motivation by examining activities that are pursued for their inherent satisfaction rather than for external rewards. The theory provides a framework for understanding how individuals achieve a state of deep focus and involvement with activity, creating an optimal state of consciousness, frequently called "flow."

In the initial phase of this thesis pilot and main studies, a scale devised by Muñoz-Carril et al. (2021) is employed, integrating elements from the Technology Acceptance Model (TAM), Expectancy-Confirmation Theory (ECT), and Flow Theory. This scale served as an instrument to assess collaborative learning within the context of MPAD. The survey was originally conceived and developed for application within computer-supported collaborative learning. The survey is adapted for and utilized within the context of collaborative learning supported by virtual reality technology.

Table 14 *Collaborative Learning Assessment*

COLLABORATIVE LEARNING ASSESSMENT							
TAM (Technology Acceptance Model), ECM (The Expectation and Confirmation Model) and Flow Theory Adaptation Scale							
Questionnaire items and descriptive statistics.							
Construct			**Very Unlikely**	**Unlikely**	**Neutral**	**Likely**	**Very Likely**
Perceived ease of use	PEOU 1	Working collaboratively in a virtual environment was easy for me.					
	PEOU 2	I found it easy to use a methodology based on collaborative online work to learn within the framework of the course.					
	PEOU 3	As I progressed through the course, I found it easier to work in a collaborative virtual environment.					
	PEOU 4	In general, I think it was easy to work collaboratively and remotely with members of my group.					
Perceived usefulness	PUSS 1	Collaborative work processes have improved my academic performance in the subject.					
	PUSS 2	Working collaboratively with my group has improved the efficacy of my learning about issues covered in this course.					
	PUSS 3	Working collaboratively has helped me to learn the course content better.					
	PUSS 4	The collaborative work we did in my group was useful for me to achieve the course competencies.					
	PUSS 5	The collaborative work we did in my group helped me to effectively complete the various tasks and activities required by the course.					
Attitude	ATTL1	I enjoy learning collaboratively.					
	ATTI2	Collaborative work is a good method of learning.					
	ATTI.3	For me it is rewarding to do academic tasks collaboratively.					
	ATTI.4	I like the idea of working collaboratively to learn.					
Confirmation	CONF 1	My experience of working collaboratively in a virtual environment was better than I expected.					
	CONE 2	Having used a method of working collaboratively as a learning system during this course, it was better than I thought it would be.					
	CONF 3	Generally, most of my expectations were met about the online collaborative working methods used in the course.					
Perceived enjoyment	PENJ 1	Working collaboratively in the virtual environment was enjoyable.					
	PENJ.2	I enjoyed working collaboratively with the members of my group.					
	PENJ 3	I enjoyed the sensation of working collaboratively in a virtual environment.					
Satisfaction	SATI1	After having done the course, I feel satisfied to have used online collaborative working processes as a method to learn.					
	SATI 2	I am satisfied with the online collaborative working methodology used in the course.					
	SATI 3	I loved the experience of working collaboratively in a virtual environment during the course.					
	SATI 4	I am satisfied with the level of skills acquired during the course thanks to online collaborative working.					
Perceived impact on learning	PIMI. 1	Having used a method based on online collaborative working during the course, it has made a positive impact on learning the subject.					
	PIML. 2	Being part of a virtual collaborative working team was a significant, valuable help to me in improving my learning processes.					
	PIML 3	I gained better understanding of some concepts and practices in the course thanks to the online collaborative work with the members of my group.					
	PIMI. 4	Online collaborative working helped me to perform academically.					

The Collaborative Learning Assessment items are descriptively analyzed, highlighting the main constructs of the survey: Perceived Ease of Use (PEOU), Perceived

Usefulness (PUS), Attitude (ATTI), Confirmation (CONF), Perceived Enjoyment (PENJ), Satisfaction (SATI), and Perceived Impact on Learning (PIMP) (Table 14). The assessment used a 5-point Likert scale, and the mean values of the items for each construct were calculated to facilitate this analysis. Table 15 illustrates that every construct was measured with a total of 38 respondents.

Table 15 *Descriptive Analysis of The Collaborative Learning Assessment*

Means, Mode, Standard Deviations and Rage of the Collaborative Learning Assessment Constructs							
	Perceived Ease of Use	Perceived Usefulness	Attitude	Confirmation	Perceived Enjoyment	Satisfaction	Perceived Impact on Learning
N	38	38	38	38	38	38	38
Missing	0	0	0	0	0	0	0
Mean	4.2895	4.0632	4.4737	4.3596	4.7105	4.4342	4.2697
Median	4.25	4.53	4.75	4.6667	5	4.5	4.5
Mode	4.25	4.60	5.00	4.67	5.00	4.50	4.75
Std. Deviation	0,396	0,495	0,586	0,650	0,381	0,467	0,659
Range	1.50	1.60	1.75	2.67	1.33	1.75	2.25

For the Perceived Ease of Use (PEOU), the mean score is 4.29, the average rating given by respondents, indicating a generally high ease of use as perceived by the respondents (Table 16). The median score, the middle value when all responses are ordered from lowest to highest, is 4.25, while the mode, defined as the most frequently occurring score, is also 4.25. The standard deviation, a measure of the dispersion from the mean, is 0.396, indicating that most responses are close to the mean. The range, defined as the difference between the highest and lowest scores, is 1.50. The number of responses and the percentage of PEOU are illustrated in Figure 36.

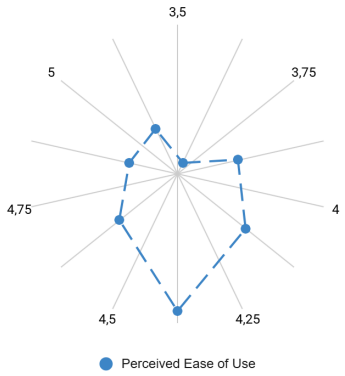


Figure 36 The Mean Rates and Statement Rate for “Perceived Ease of Use” of MPAD

Table 16 *Statement Rates of "Perceived Ease of Use" of MPAD*

	Perceived Ease of Use													
The Mean Rates	3,5		3,75		4		4,25		4,5		4,75		5	
	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Perceived Ease of Use	%2.6	1	%13.2	5	%18.4	7	%28.9	11	%15.8	6	%10.5	4	%10.5	4

The mean score for Perceived Usefulness (PUS) is 4.06, suggesting that respondents find the collaborative learning tools moderately useful. The median score is 4.53, meaning half of the responses are below this value and half are above. The most frequent response (mode) is 4.60, indicating this is the most common perception of usefulness among respondents. The standard deviation is 0.495, showing a moderate degree of variability in the responses. The range is 1.60, indicating the difference between the highest and lowest scores for PUS (Table 17). The number of responses and the percentage of PUS are illustrated in Figure 37.

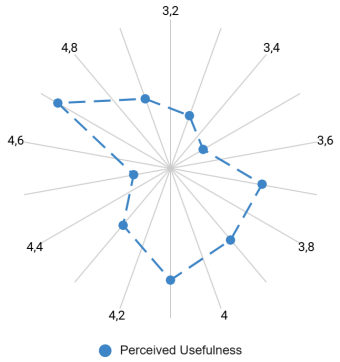


Figure 37 The Mean Rates and Statement Rates for “Perceived Usefulness” of MPAD

Table 17 *Statement Rates of "Perceived Usefulness" of MPAD*

	Perceived Usefulness															
The Mean Rates	3,2		3,4		3,6		3,8		4		4,2		4,4		4,6		4,8	
	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Perceived Usefulness	%7.9	3	%5.3	2	%13.2	5	%13.2	5	%15.8	6	%10.5	4	%5.3	2	%18.4	7	%10.5	4

The Attitude construct demonstrated the highest mean score at 4.47, indicating a notably positive attitude towards MPAD. The median score is 4.75 and the mode is 5.00, representing the most frequent rating. The standard deviation is 0.586, indicating a moderate degree of variability, with a range of 1.75 (Table 18). Figure 38 illustrates the number of responses and the percentage of ATTI.

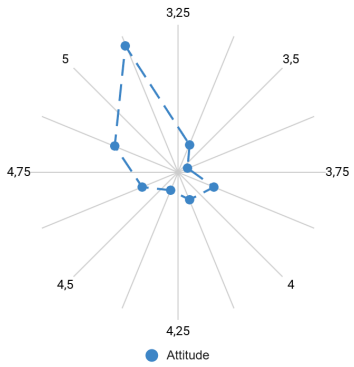


Figure 38 The Mean Rates and Statement Rate for “Attitude” of MPAD

Table 18 *Statement Rates of "Attitude" of MPAD*

	Attitude													
The Mean Rates	3,25		3,5		3,75		4		4,25		4,5		4,75		5	
	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Attitude	%7.9	3	%2.6	1	%10.5	4	%7.9	3	%5.3	2	%10.5	4	%18.4	7	%36.8	14

The mean score for confirmation is 4.36, which indicates a high level of consensus among respondents that their expectations have been met. The median score is 4.67, and the mode is also 4.67, which reflects the most common rating. The standard deviation is 0.650, indicating a higher degree of variability in responses, with a range of 2.67 (Table 19). The number of responses and the percentage of CONF is illustrated in Figure 39.

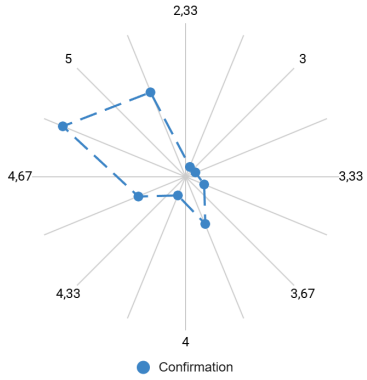


Figure 39 The Mean Rates and Statement Rate for "Confirmation" of MPAD

Table 19 *Statement Rates for "Confirmation" of MPAD*

	Confirmation													
The Mean Rates	2,33		3		3,33		3,67		4		4,33		4,67		5	
	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Confirmation	%2.6	1	%2.6	1	%5.3	2	%13.2	5	%5.3	2	%13.2	5	%34.2	13	%23.7	9

The highest mean score was obtained for Perceived Enjoyment (4.71), with a median score of 5.00 and a mode score of 5.00. This indicates that respondents derive high enjoyment from utilizing collaborative learning tools. The standard deviation is 0.381, indicating that the responses are concentrated around the mean and exhibit minimal variation. The range is 1.33 (Table 20). The number of responses and the percentage of PENJ is illustrated in Figure 40.

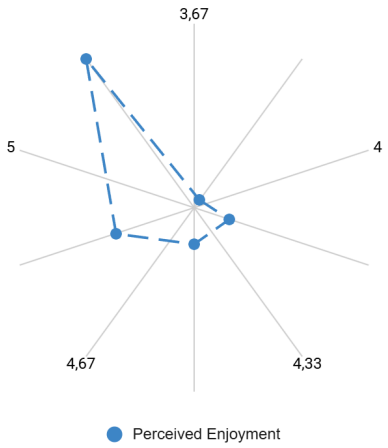


Figure 40 The Mean Rates and Statement Rate for “Perceived Enjoyment” of MPAD

Table 20 *Statement Rates for "Perceived Enjoyment" of MPAD*

	Perceived Enjoyment									
The Mean Rates	3,67		4		4,33		4,67		5	
	%	N	%	N	%	N	%	N	%	N
Perceived Enjoyment	%2.6	1	%10.5	4	%10.5	4	%23.7	9	%52.6	20

The mean score for satisfaction is 4.43, indicating a high level of satisfaction among users. The median and mode scores are both 4.50, indicating that this is the most frequently occurring rating. The standard deviation is 0.467, indicating moderate variability in responses, with a range of 1.75 (Table 21). Figure 41 illustrates the number of responses and the percentage of SATI.

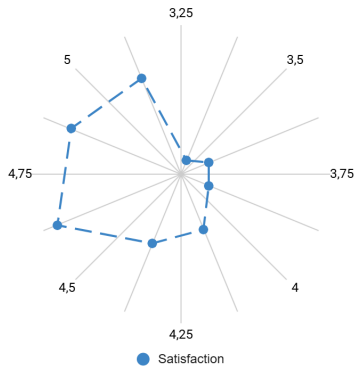


Figure 41 The Mean Rates and Statement Rate for “Satisfaction” of MPAD

Table 21 *Statement Rates for "Satisfaction" of MPAD*

	Satisfaction															
The Mean Rates	3,25		3,5		3,75		4		4,25		4,5		4,75		5	
	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Satisfaction	%2.6	1	%5.3	2	%5.3	2	%10.5	4	%13.2	5	%23.7	9	%21.1	8	%18.4	7

The mean score for Perceived Impact on Learning is 4.27, indicating a positive impact on learning as respondents perceive. The median score is 4.50, the mode is 4.75, and the standard deviation is 0.659, suggesting higher response variability. The range is 2.25 (Table 22). Figure 42 illustrates the number of responses and the percentage of PIMP.

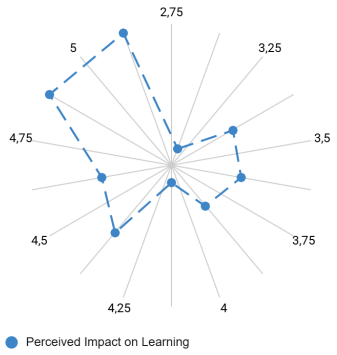


Figure 42 The Mean Rates and Statement Rate for “Perceived Impact on Learning” of MPAD

Table 22 *Statement Rates for "Perceived Impact on Learning" of MPAD*

	Perceived Impact on Learning																	
	2,75		3,25		3,5		3,75		4		4,25		4,5		4,75		5	
	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N
Perceived Impact on Learning	%2.6	1	%10.5	4	%10.5	4	%7.9	3	%2.6	1	%13.2	5	%10.5	4	%21.1	8	%21.1	8

The results of the analysis of the surveys indicate a predominantly positive perception and attitude towards the collaborative learning tools, characterized by high levels of enjoyment, satisfaction, and perceived impact on learning.

4.4.2 Correlation Matrix of the Collaborative Learning Assessment

The correlation matrix analysis reveals several significant relationships among the variables, as indicated by the two-tailed significance value ($p < 0.05$). Due to its ordinal nature, the Likert scale typically yields non-parametric data. Consequently,

Spearman's rank correlation measures the strength and direction of an association between constructs (Table 23).

Table 23 *Correlation Matrix with Significance Highlighted*

Correlation Matrix of the Collaborative Learning Assessment								
	Spearman's rho	**PEOU**	**PUS**	**ATTI**	**CONF**	**PENJ**	**SATI**	**PIMP**
PEOU	Correlation Coefficient	1	0,203	0,001	0,293	0,315	0,162	0,175
	Sig. (2-tailed)	.	(0,222)	(0,997)	(0,074)	(0,054)	(0,33)	(0,293)
PUS	Correlation Coefficient	0,203	1	0,173	0,264	,398*	,534**	,588**
	Sig. (2-tailed)	(0,222)	.	(0,299)	(0,110)	(0,013)	(0,001)	(0,000)
ATTI	Correlation Coefficient	0,001	0,173	1	,438**	,345*	,444**	,423**
	Sig. (2-tailed)	(0,997)	(0,299)	.	(0,006)	(0,034)	(0,005)	(0,008)
CONF	Correlation Coefficient	0,293	0,264	,438**	1	,446**	,530**	,465**
	Sig. (2-tailed)	0,074	0,11	(0,006)	.	(0,005)	(0,001)	(0,003)
PENJ	Correlation Coefficient	0,315	,398*	,345*	,446**	1	,644**	,364*
	Sig. (2-tailed)	0,054	(0,013)	(0,034)	(0,005)	.	(0,000)	(0,025)
SATI	Correlation Coefficient	0,162	,534**	,444**	,530**	,644**	1	,564**
	Sig. (2-tailed)	0,33	(0,001)	(0,005)	(0,001)	(0,000)	.	(0,000)
PIMP	Correlation Coefficient	0,175	,588**	,423**	,465**	,364*	,564**	1
	Sig. (2-tailed)	0,293	(0,000)	(0,008)	(0,003)	(0,025)	(0,000)	.

Note. *Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

- There are significant positive correlations between Perceived Usefulness (PUS) and Perceived Enjoyment (PENJ), Satisfaction (SATI), and Perceived Improvement (PIMP) ($p = 0.013$; $p = 0.000$; $p < 0.000$).
- A significant positive correlation was observed between attitude (ATTI) and confidence (CONF), perceived enjoyment (PENJ), satisfaction (SATI), and perceived improvement (PIMP) ($p = 0.006$; $p = 0.034$; $p = 0.005$; $p = 0.008$).

- A significant positive correlation was observed between confidence (CONF) and perceived enjoyment (PENJ), satisfaction (SATI), and perceived improvement (PIMP) ($p = 0.005$; $p = 0.001$; $p = 0.003$). Also CONF has correlation with ATTI as mentioned above.
- Similarly, a significant positive correlation was found between perceived enjoyment (PENJ) and satisfaction (SATI) and perceived improvement (PIMP) ($p < 0.000$; $p = 0.025$). Also PENJ has correlation with PUS, ATTI and CONF as mentioned above.
- Finally, a significant positive correlation was identified between satisfaction (SATI) and perceived improvement (PIMP) ($p < 0.000$). Also SATI has correlation with PUS, ATTI, CONF and PENJ as mentioned above.
- As mentioned above, PIMP displayed correlations between PUS, ATTI, CONF, PENJ and SATI.
- The data shows that PEOU does not have statistically significant correlations with other variables in the sample. This could suggest that, in this context, ease of use might not be as influential as other factors.

4.4.3 Non-Parametric Analysis of the Collaborative Learning Assessment

Fisher's Exact Test is conducted to determine the statistically significant correlations between the answers to the questions in the demographic survey and Collaborative Learning Assessment statements.

- "Have you ever used tools in a VR environment?"

- "How often do you use computer programs?"
- "Have you ever used computer design software for an architecture class?"
- "Have you ever experienced a Metaverse environment?"

The responses to the five-point Likert scale items from the questionnaire were grouped into two categories for analysis using Fisher's exact test, which is employed for the analysis of non-parametric variables. Specifically, for Question 1 (VR Tool Experience) and Question 2 (The Metaverse Experience), responses were divided into "Never" and "Once to Regularly." In this context, the mean values of the responses "Rarely, Occasionally, Often, Regularly" were calculated. Additionally, for Question 3 (Computer Program Experience) and Question 4 (The Computer Design Program Experience), responses were categorized into two groups: 1) "Never, Rarely, Occasionally," and 2) "Often, Regularly." This categorization assessed the participants' familiarity and expertise with computer usage.

As Figures 43, 44, and 45 demonstrate, the Fisher's Exact Test results indicate statistically significant associations between VR tool experience and various variables. The results demonstrated that students who had never used VR tools before and who used them once or more experienced MPAD differently.

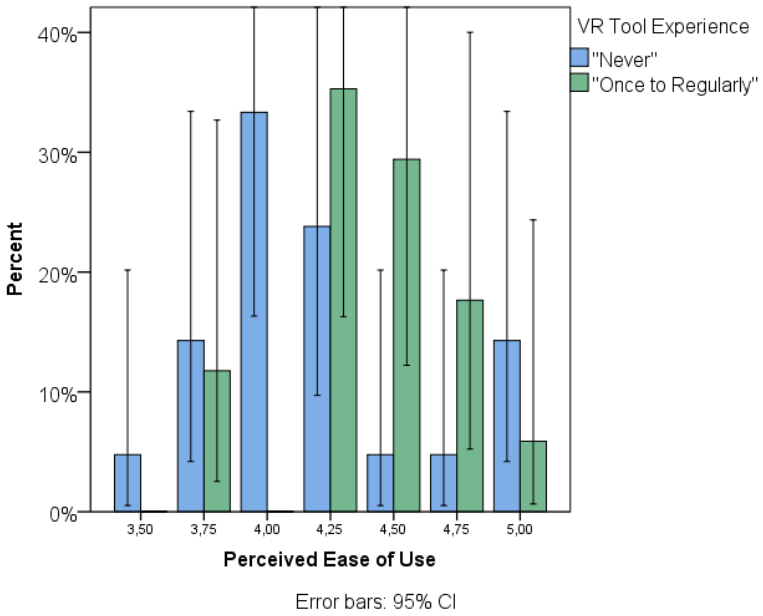


Figure 43 Comparison of Perceived Ease of Use Between Different Levels of VR Tool Experience

Table 24 *Association Between VR Tool Experience and Perceived Ease of Use*

VR Tool Experience - Perceived Ease of Use: Chi-Square Tests		
	Value	Exact Sig. (2-sided)
Fisher's Exact Test	12,638	0,026*
N of Valid Cases	38	

Note. *Correlation is significant at the 0.05 level (2-tailed).

It was found that there is a statistically significant association between VR Tool Experience and Perceived Ease of Use (peou), Fisher's Exact Test (1, N=38) = 12.638, p = 0.026; less than the threshold value of significant level (Table 24). This indicates that those with no former familiarity are less likely to perceive ease of use (PEOU) of the application and process, given that the scores of 4.50, 4.75, and 5.00 (Likely=4; Very Likely=5) were lower than those who had "Once to Regularly" experienced the VR tool (Figure 43).

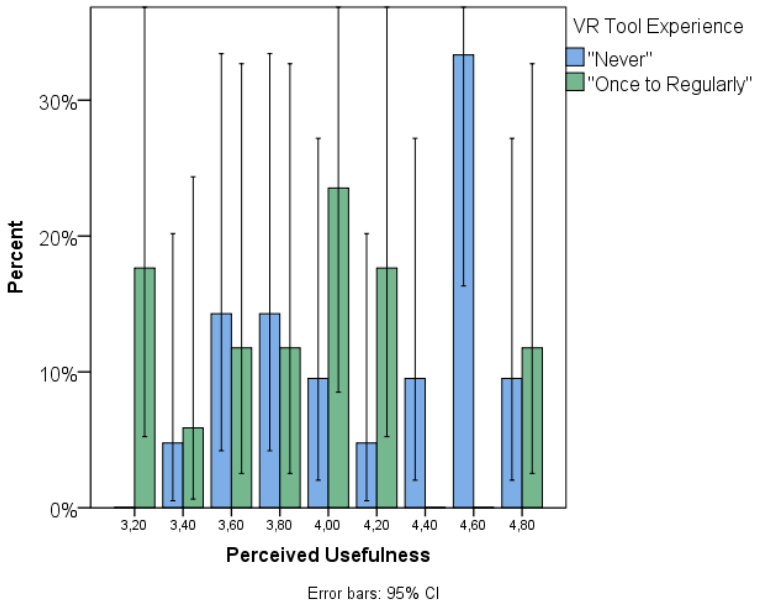


Figure 44 Comparison of Perceived Usefulness Between Different Levels of VR Tool Experience

Table 25 *Association Between VR Tool Experience and Perceived Usefulness*

VR Tool Experience - Perceived Usefulness		
	Value	Exact Sig. (2-sided)
Fisher's Exact Test	13,697	0,048*
N of Valid Cases	38	

Note. *Correlation is significant at the 0.05 level (2-tailed).

Similarly, it was found that VR Tool Experience (vrtool_exp2) is significantly associated with Perceived Usefulness (PUS), Fisher's Exact Test (1, N=38) = 12.638, p = 0.048 (Table 25). Those without prior experience with VR tools find the collaborative learning process and application more useful (PUS), with a notable concentration at higher scores (4.60). This indicates that familiarity and repeated use of VR tools might moderate the perceived usefulness (Figure 44).

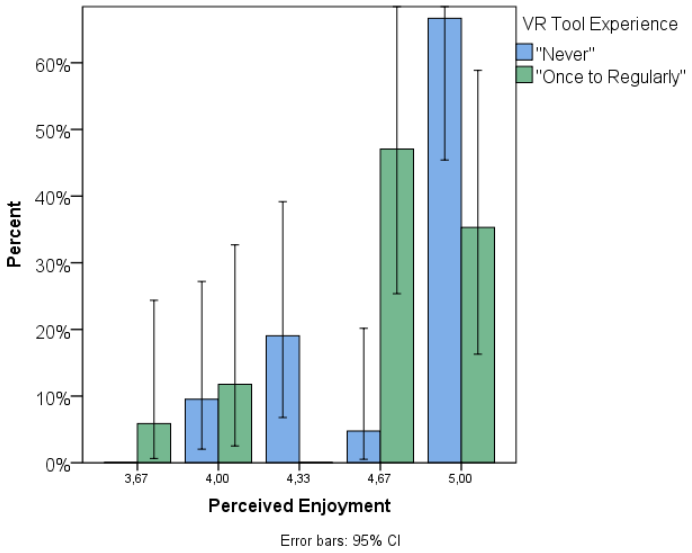


Figure 45 Comparison of Perceived Enjoyment Between Different Levels of VR Tool Experience

Table 26 *Association Between VR Tool Experience and Perceived Enjoyment*

VR Tool Experience - Perceived Enjoyment		
	Value	Exact Sig. (2-sided)
Fisher's Exact Test	12,968	0,003**
N of Valid Cases	38	

Note. **Correlation is significant at the 0.01 level (2-tailed).

Furthermore, the VR Tool Experience is significantly associated with Perceived Enjoyment (PENJ), as demonstrated by the Fisher's Exact Test (1, N=38) = 13.832, p = 0.003, well below the threshold value 0.05 (Table 26). This demonstrates the influence of the VR Tool Experience on the enjoyment derived from VR headset and application experiences. Consequently, those not previously experienced VR tools tend to have higher perceived enjoyment levels (PENJ; Very Likely=5) (Figure 45).

There are notable differences between individuals who lack prior experience with the metaverse (30 participants) and those with some exposure (8 participants). Fisher's exact test revealed a significant difference in how these different metaverse experience levels relate to measures of confirmation and perceived usefulness in the virtual collaboration learning environment.

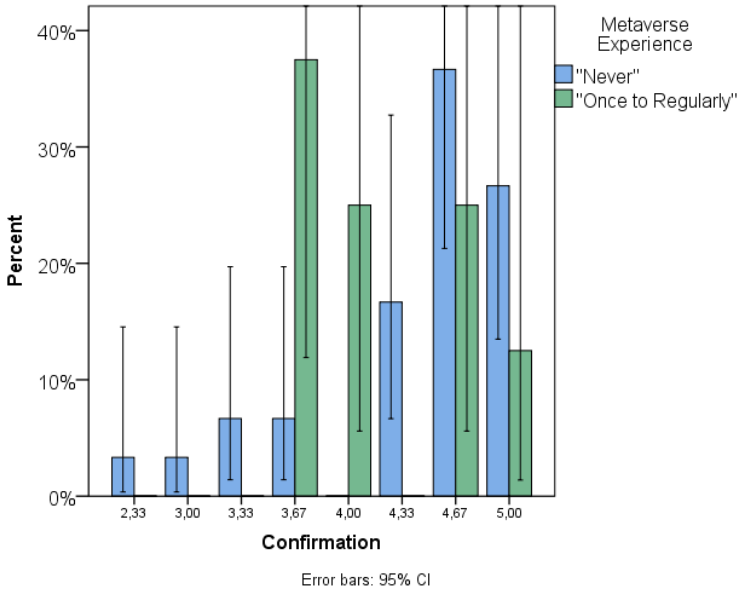


Figure 46 Comparison of Confirmation Between Different Levels of Metaverse Experience

Table 27 *Association Between Metaverse Experience and Confirmation*

Metaverse Experience - Confirmation		
	Value	Exact Sig. (2-sided)
Fisher's Exact Test	11,665	0,046*
N of Valid Cases	38	

Note. *Correlation is significant at the 0.05 level (2-tailed).

The findings indicate that familiarity with the metaverse significantly fulfills expectations in collaborative virtual settings (Fisher's exact test, $p = 0.046$) (Table 27). Participants who have never engaged with the metaverse tend to report higher

confirmation (CONF) scores, indicating that their expectations are frequently met or exceeded. In contrast, those who have experienced the metaverse "Once to Regularly" tend to have intermediate confirmation scores, suggesting a more varied experience in meeting expectations (Figure 46).

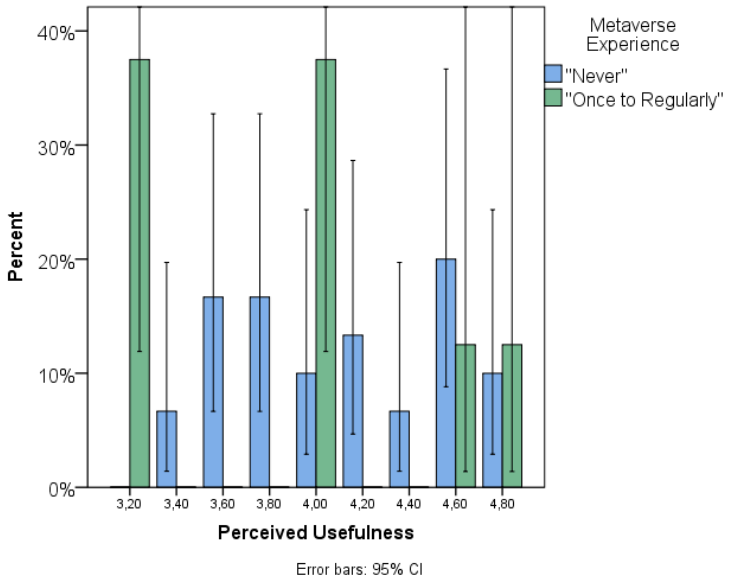


Figure 47 Comparison of Perceived Usefulness Between Different Levels of Metaverse Experience

Table 28 *Association Between Metaverse Experience and Perceived Usefulness*

Metaverse Experience - Perceived Usefulness		
	Value	Exact Sig. (2-sided)
Fisher's Exact Test	13,832	0,013*
N of Valid Cases	38	

Note. *Correlation is significant at the 0.05 level (2-tailed).

Metaverse Experience was found to be significantly associated with Perceived Usefulness (PUS), Fisher's Exact Test (1, N=38) = 13.832, p = 0.013 (28). Regarding

perceived usefulness (PUS), respondents with no prior metaverse experience show a broader range of scores, particularly at intermediate and higher levels (3.60, 3.80, 4.60; where Neutral=3; Likely=4; Very Likely=5). On the other hand, individuals who engage in the metaverse regularly or occasionally report lower to intermediate perceived usefulness scores (3.20, 4.00, where Neutral=3; Likely =4). This indicates that initial encounters with the metaverse may lead to varied perceptions of its practical application and effectiveness. Meanwhile, more frequent users may develop a more critical perspective, resulting in more consistent lower and intermediate usefulness ratings (Figure 47).

4.4.4 Game Experience Survey

The final phase of the group test was adapted from Martin-Dorta et al. (2014). Participants completed a questionnaire about their gaming experience at the end of the workshop sessions. Each statement in the questionnaire reflects a different aspect of the MPAD experience. The five-point Likert scale, which forms the basis of the Game Experience Survey, is presented in Table 29.

Table 29 *Game Experience Survey*

Game Experience Survey						
Students' answers to attitude questionnaire regarding the game experience						
Item n°	**Statement**	**Very Unlikely**	**Unlikely**	**Neutral**	**Likely**	**Very Likely**
1	MPAD was easy to understand.					
2	I felt capable of solving tasks.					
3	The game stimulates my interest.					
4	I think it's a nice tool for development of the spatial ability.					
5	I would recommend this application to my classmates.					
6	I think that metaverse and game-based learning is a good learning system.					
7	I would have rather performed this course with the teacher physically present.					

This final questionnaire takes a more holistic view of the MPAD experience. The first statement assesses the comprehensibility of the application, while the second explores the participants' experience of solving design tasks with a partner using virtual reality controllers.

Later questions explore general interest in the application and whether participants would recommend it to others. Participants' opinions on the development of spatial skills using MPAD and the effectiveness of the learning system are also sought. The final statement aims to compare the traditional studio environment with the individual-collaborative design process in a virtual context.

Table 30 *Distribution of The Responses of "Game Experience Survey"*

		Very Unlikely		Unlikely		Neutral		Likely		Very Likely	
		%	N	%	N	%	N	%	N	%	N
1	MPAD was easy to understand.	0,00%	**0**	2,60%	**1**	10,50%	**4**	36,80%	**14**	50,00%	**19**
2	I felt capable of solving tasks.	0,00%	**0**	2,60%	**1**	15,80%	**6**	28,90%	**11**	52,60%	**20**
3	The game stimulates my interest.	0,00%	**0**	0,00%	**0**	0,00%	**0**	21,10%	**8**	78,90%	**30**
4	I think it's a nice tool for development of the spatial ability.	0,00%	**0**	0,00%	**0**	7,90%	**3**	23,70%	**9**	68,40%	**26**
5	I would recommend this application to my classmates.	0,00%	**0**	0,00%	**0**	0,00%	**0**	21,10%	**8**	78,90%	**30**
6	I think that metaverse and game-based learning is a good learning system.	0,00%	**0**	0,00%	**0**	2,60%	**1**	23,70%	**9**	73,70%	**28**
7	I would have rather performed this course with the teacher physically present.	31,60%	**12**	31,60%	**12**	15,80%	**6**	13,20%	**5**	7,90%	**3**

The answers to the statements demonstrate the results illustrated in Table 30, Figure 48 and 49 as follows:

- Regarding the statement (1) "MPAD was easy to understand," 19 participants found it very easy to comprehend, with 14 participants also finding it understandable. Meanwhile, 4 participants were neutral, and just 1 participant indicated slight difficulty in understanding.
- For the statement (2) "I felt capable of solving tasks," 20 participants were very confident in their ability to solve tasks, 11 participants felt capable, and 6 participants were neutral in their response. Only 1 participant expressed some doubt.

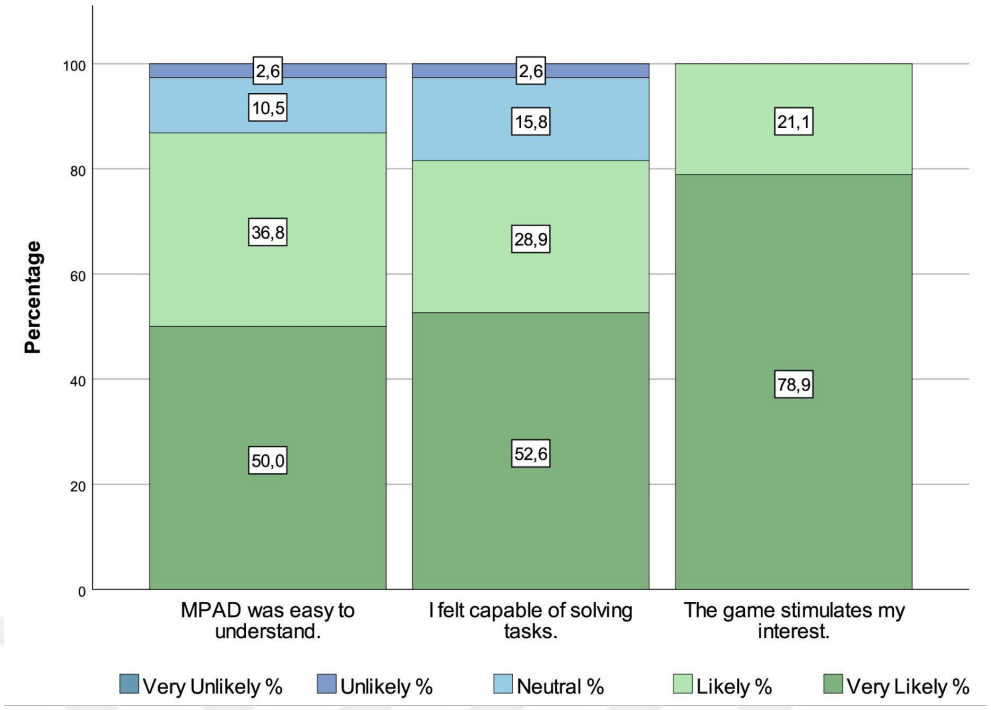


Figure 48 Distribution of Three Responses of "Game Experience Survey"

- In response to the statement (3) "The game stimulates my interest," the 30 of the participants indicated that they highly enjoyed the experience, while 8 participants indicated that they enjoyed it.
- Regarding the statement (4) "I think it's a nice tool for the development of spatial ability," 26 participants strongly believed that the tool was effective for enhancing spatial skills, with 9 participants agreeing and 3 participants being undecided. None of the participants disagreed with this statement.

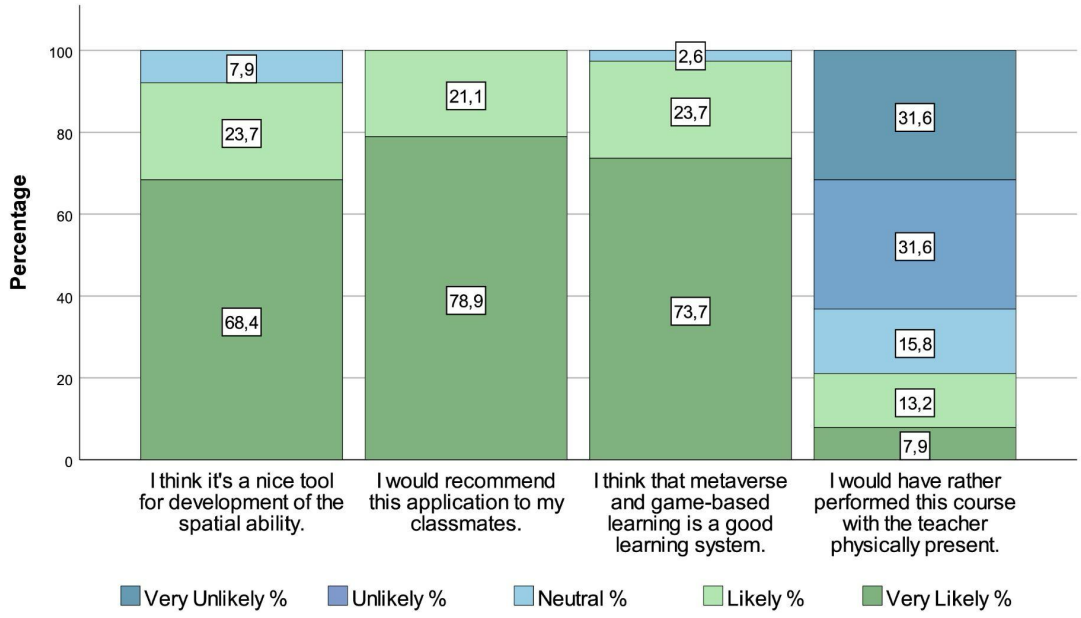


Figure 49 Distribution of Four Responses of "Game Experience Survey"

- In response to the statement (5) "I would recommend this application to my classmates," 30 participants were highly inclined to recommend the application, while 8 participants were inclined to do so. There were no participants who were neutral or against recommending it.
- Concerning the statement (6) "I think that metaverse and game-based learning is a good learning system," 28 participants were very supportive of this learning approach, with 9 participants agreeing, and 1 participant remaining neutral. No participants disagreed with this statement.
- For the statement (7) "I would have rather performed this course with the teacher physically present," 24 participants not preferred having a teacher physically present. However, 6 participants were neutral, while 8 participants favored the conventional setup.

CHAPTER 5

DISCUSSIONS AND CONCLUSION

The results of the MPAD experimental study highlight the potential of using game-based and metaverse-based approaches in basic design education for architecture. The implementation of a collaborative virtual environment proves to be an effective design medium, with CIX elements facilitating an exploration design tool alternative within virtual reality.

This chapter discusses the results, identifies limitations, and suggests further directions for research. The statistical analyses, demographic results, and participant reviews have been detailed in Chapter 4. Here, a comprehensive evaluation of the findings is presented, with a focus on their contributions to architectural design processes.

5.1 Discussions of the Results

The statistical analysis comprises the Collaborative Learning Assessment (CLA), demographic data, questions regarding familiarity with digital technologies, and the Game Experience Survey. The CLA and Game Experience Survey statements are evaluated through a statistical analysis to assess the impact of the collaborative basic design and the effectiveness of the VR-based environment. The preliminary stage of

the analysis process entails a descriptive evaluation of the CLA and Game Experience Survey statements. Subsequently, an examination of the associations between the CLA constructs is conducted. Accordingly, a correlation matrix is produced for the analysis. Finally, a non-parametric statistical analysis is performed to test for differences between the CLA constructs and the digital familiarity questions. The digital familiarity questions comprise the participants' prior VR tools, computer programs, design software, and metaverse experiences. The findings of the experimental study are elaborated in Chapter 4.

The descriptive analysis of the CLA indicates that participants generally hold a positive perception of MPAD and perceive positive outcomes.

- The study assesses multiple variables associated with collaborative learning tools. The results of the construct statements indicate that mean values exceeding 4 indicate a high probability of agreement with the statements on a 5-point Likert scale. An analysis of the Perceived Usefulness statements revealed a mean value of 4.06, which is lower than the other constructs. This indicates that the participants were uncertain about the utility of MPAD. Nevertheless, no participant assigned a value below the average. The highest mean value (4.71) and most consistent responses were observed in the Perceived Enjoyment construct, which indicated that a playful approach is an effective method for capturing the participants' interest.

- The confirmation values indicate a high level of agreement that the expectations were met. However, it displays the highest standard deviation and range, indicating a higher level of variability and differing user experiences. Similarly, in the Perceived Impact on Learning, a considerable proportion of respondents indicated that they perceived a strong impact on their learning. However, it is notable that there is considerable variation in the experiences reported.
- The attitude construct has the highest mean score, indicating a very positive reception. The mode of 5.00 suggests that the highest rating was frequently given. Satisfaction has a high mean score and moderate variability, suggesting overall high satisfaction with some degree of differing opinions.
- Overall, respondents showed a positive perception of the tools, highlighting high levels of feedback.

Spearman's rank correlation matrix use to analyze the correlations among the seven constructs of the Collaborative Learning Assessment which include ease of use, usefulness, the impact of learning, enjoyment, attitude, fulfillment of expectations, and satisfaction with the collaborative learning experience. It demonstrates that there are significant positive correlations. The results can be analyzed as follows:

- The application's usefulness (pus) is significantly correlated with enjoyment (penj), satisfaction (sati) and promotes the learning outcomes at the end (pimp).

- Similarly, the rate of meeting the expections toward the application (conf) shows strong correlations with perceived enjoyment (penj) and satisfaction (sati) from application. Also, perceived impact on learning (pimp) affects the expectations.
- The attitude (atti) toward the collaborative learning application is positively linked to the expectation (conf) and how they met, perceived enjoyment, satisfaction. It affects the learning outcomes (pimp).
- Overall, perceived impact on learning is correlated with all other factors except for perceived ease of use, which does not show significant correlations with any other variables. This suggests that the application's ease of use may be less influential than other factors in this context.

The correlations between CLA constructs and the digital familiarity questions, which are based on prior experience with the technologies, provide significant results. The correlations between CLA constructs and digital familiarity reveal that prior VR experience positively influences perceived ease of use and usefulness of the VR-based application. Additionally, those without VR experience report higher perceived enjoyment (PENJ). Participants new to the metaverse often report high levels of fulfillment, with expectations often met or exceeded, whereas regular or occasional metaverse users tend to report lower perceived usefulness of the application.

The final analysis in the post-survey phase is the gaming experience, with each statement in the questionnaire reflecting a different aspect of the MPAD experience.

Most participants reported a highly positive experience with MPAD, enjoying the platform and recommending it to others. The concept of the metaverse and game-based learning was widely understood, with consensus on its effectiveness in enhancing spatial skills. While confidence in task-solving was generally high, some participants expressed neutrality or uncertainty. Opinions varied on the need for a tutor in the virtual environment, with most preferring to work independently, though a smaller group favored conventional studio methods.

- The majority of participants had a highly positive experience with MPAD, with nearly all expressing enjoyment. Similarly, most respondents indicated that they would recommend MPAD to others.
- A total of 33 participants found MPAD easy to comprehend. Meanwhile, 4 participants were neutral, and one indicated slight difficulty understanding.
- The majority of participants expressed positive views on the metaverse and game-based learning as effective learning systems, whereas one participant maintained a neutral stance.
- Most participants expressed the view that the tool was effective for enhancing spatial skills, yet three participants remained undecided. None of the participants expressed disagreement with this statement.
- A total of 31 participants expressed confidence in their ability to solve tasks, while six participants indicated a neutral response. One participant indicated some degree of uncertainty.

- There was a divergence of opinion as to the necessity of a tutor inside the virtual environment during the experiment. 24 participants not preferred having a teacher physically present and 6 participants remained neutral, while 8 participants favored the conventional setup.

5.2 Discussions of the Participant Feedback

Participants highlighted several positive aspects of their MPAD experience, particularly the enhanced comprehension and intuitive use of the virtual reality (VR) environment. This immersive experience also helped them overcome initial challenges in visualizing two-dimensional designs in a three-dimensional space, making the design process easier as they progressed. Additionally, participants found the VR technology to be more intuitive and user-friendly compared to traditional computer-based methods.

They also predicted that implementing VR methods for first-year students could enhance their understanding and improve academic performance. Furthermore, participants highlight the potential of using VR to bridge the gap between virtual and real-life design in both educational and professional contexts.

The first of the key suggestions from the participant reviews is the need for multiple sessions as an important factor in the familiarization process for both the MPAD and the VR environment. Secondly, there is a need for support for larger groups, and

thirdly, additional features are required, including object snapping through surfaces, multiple element selection, and transformation.

The criticisms primarily focused on the challenges encountered when collaborating with partners, the difficulty in identifying specific catalog elements, the lack of certain shapes, and the issues associated with object snapping. It is possible that some of the suggestions and criticisms regarding the gameplay and interface may be addressed in future implementations.

5.3 Limitations and Directions for Future Studies

The relatively small sample size of 38 participants represents a significant limitation of the thesis. In future applications of MPAD, the workshops can be conducted with the objective of increasing participation.

In addition to the feedback provided by participants regarding the interface and gameplay limitations of MPAD, one of the constraints associated with MPAD was the inability to conduct collaborative sessions with more than two participants. This was due to the limited internet capacity encountered in the multi-user environment in the experiment places at both universities, Bilkent University and Ostim Technical University. In future applications of MPAD, the technical limitations can be identified.

MPAD's game-based environment and interface can be further developed to provide greater flexibility and capability in 3D design and form creation. The focus on

conceptualization in the basic design phases can be extended to include different levels of architectural design phases.

MPAD is a limited virtual environment experiment that can be extended onto different metaverse environments. The outputs of the thesis and the data obtained aim to create a basis for architectural studios to be realized in the Metaverse environment in the future.

5.4 Conclusion

In conclusion, the thesis has explored the potential of integrating novel technologies and virtual environments in architectural design education, with a particular focus on incorporating playfulness and game-based learning in the early design processes. The integration of these elements has resulted in the development and analysis of a metaverse-based collaborative virtual model for basic design. The implementation of MPAD (Metaverse-based Playground for Architectural Education) has demonstrated the potential for immersive, game-based learning approaches to enhance design education. This model leverages the foundational principles established by Friedrich Froebel, emphasizing the parts-to-whole approach and the use of geometric building blocks, and by Fabien Vienne, emphasizing topologic relationships, geometric structures, virtual cubes, and grid systems.

MPAD's collaborative and interactive environment facilitates a modern take on the traditional design studio, allowing participants to engage in the design process through

their avatars in a virtual playground. Applying the adaptation of the technology Acceptance Model (TAM) with the Expectancy-Confirmation Model (ECM) and Flow Theory and Game Experience Survey the thesis provided insights into users' experiences and attitudes toward collaborative processes of MPAD, indicating positive outcomes for undergraduate basic design education.

In conclusion, this thesis contributes to the field of research on digital and virtual technologies in architectural education. It highlights the importance of game-based learning and collaborative virtual environments. The findings demonstrate the necessity for further exploration and adaptation of these technologies to ensure the sustainability and advancement of architectural design education in the digital age.

5.5 Notes

This research was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK 1002 Project ID: 124K599). The MPAD design experiments in this study were approved by the Bilkent University Ethics Committee on February 24th, 2024 (application number 508).

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APPENDICES

APPENDIX A. Student Consent Form

Who is carrying out the study?

You are invited to participate in a study conducted by the Architecture Department as part of a research project at Bilkent University.

What is the study about?

This study looks at how an architectural basic design education utilizing the game-based learning method can be executed with the guidance of metaverse technology.

What does the study involve?

You will be asked to participate in a game application called MPAD (Metaverse-based Playground for Architectural Education). MPAD is an experience that requires a collaborative design process with specific building blocks. Participation in the MPAD will be either with the computers in the Bilkent University laboratory or virtual reality headsets and controllers, according to the group you have assigned. The researcher will ask you to complete a questionnaire before and two more after the experiment.

How much time will the study take?

It will take approximately 20 minutes inside the application, and the preparation time is about 10 minutes, which is 30 minutes.

Will the study benefit me?

The study will not benefit you directly in terms of receiving any compensation but will tell us more about how people participate in basic design courses collaboratively in a premetaverse game environment. You will also receive more detailed information about the study after your participation is completed.

Will the study involve any discomfort for me?

It is not foreseen that the study will involve any discomfort greater than one encounter in everyday life. However, motion sickness may occur due to the technology of virtual reality headsets or the motion displayed on the computer screen. If you have experienced similar discomfort before, please inform your researcher. Replacing the virtual reality headset with a computer-based application is possible if necessary. If you experience discomfort during the session, you can take a break or withdraw from participating without facing any consequences.

How will the confidentiality of my responses be ensured? How will the results be disseminated?

All aspects of the study, including results, will be confidential, and only the researchers will have access to information on participants. The group results will be written up as part of the workshop. Unidentifiable data may be used again to test new analysis techniques or hypotheses. Individual results will be kept from being reported. Individual responses will be kept confidential by assigning unique identification numbers to each participant and associating their responses only to this number. No personally identifiable information will be associated with any of the participant responses.

Can I withdraw from the study?

Participation is entirely voluntary. You are not obliged to be involved, and if you do participate, you can withdraw at any time without giving any reason and without facing any consequences, particularly vis-à-vis your relationship with Bilkent University.

Can I tell other people about the study?

Yes, you can tell other people about the study by providing them with the Researcher Bilge Sağlam's contact details. They can contact Researcher Bilge Sağlam to discuss their participation in the research project.

What if I require further information?

When you have read this information, your researcher will discuss it with you further and answer any questions you may have. Also, you are always welcome to contact any of the researchers at the contact information given above.

What if I have a complaint?

This study has been approved by the Bilkent University Department of Psychology Ethics Committee. If you have any complaints or reservations about the ethical conduct of this research, you may contact the research supervisor.

Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome. If you agree to participate in this study, please sign the informed consent form below.

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I have been asked to participate in the research project Metaverse-based Playground for Architectural Education: MPAD and give my free consent by signing this form. I acknowledge that:

1. The research project will be carried out as described above. I have read and understood the information provided and have had the opportunity to discuss the information and my involvement in the project with the researcher(s) to my satisfaction.

2. My involvement is confidential and the information gained during the study may be published, but no personal information will be used in any way that reveals my identity.

3. My consent to participate is voluntary. I may withdraw from the study at any time, without affecting my relationship with Bilkent University. I do not have to give a reason for the withdrawal of my consent.

Signed: ……...
Name: ……
Date: ……
~~~~~~

APPENDIX B. Demographic Survey



Figure B1 MPAD Demographic Survey

APPENDIX C. MPAD Post Surveys

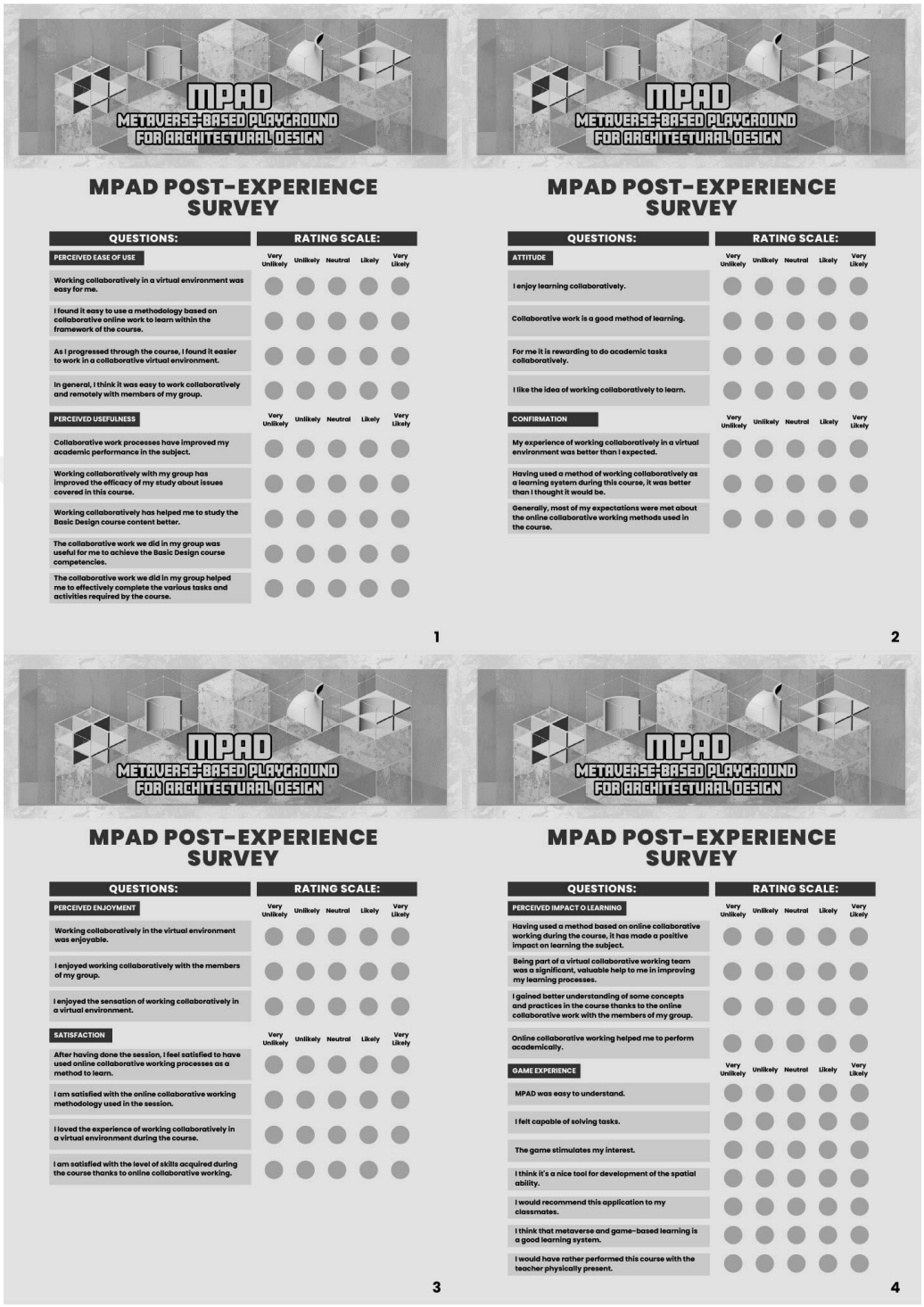
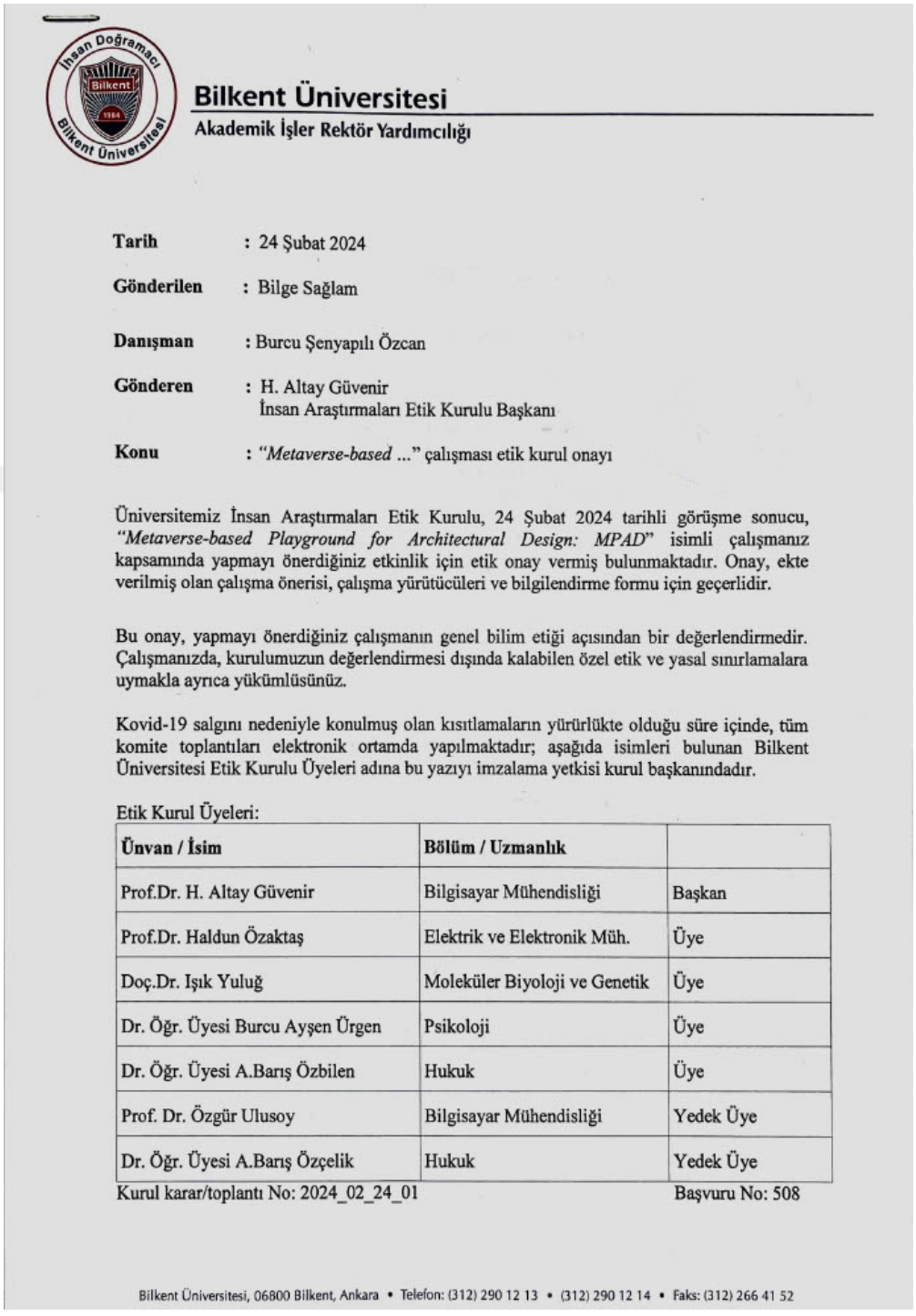


Figure C1 MPAD Workshop Post-Surveys

APPENDIX D. Research Ethics Committee Approval



Bilkent Üniversitesi
Akademik İşler Rektör Yardımcılığı

Tarih : 24 Şubat 2024

Gönderilen : Bilge Sağlam

Danışman : Burcu Şenyapılı Özcan

Gönderen : H. Altay Güvenir
İnsan Araştırmaları Etik Kurulu Başkanı

Konu : *"Metaverse-based ..."* çalışması etik kurul onayı

Üniversitemiz İnsan Araştırmaları Etik Kurulu, 24 Şubat 2024 tarihli görüşme sonucu, *"Metaverse-based Playground for Architectural Design: MPAD"* isimli çalışmanız kapsamında yapmayı önerdiğiniz etkinlik için etik onay vermiş bulunmaktadır. Onay, ekte verilmiş olan çalışma önerisi, çalışma yürütücüleri ve bilgilendirme formu için geçerlidir.

Bu onay, yapmayı önerdiğiniz çalışmanın genel bilim etiği açısından bir değerlendirmedir. Çalışmanızda, kurulumuzun değerlendirmesi dışında kalabilen özel etik ve yasal sınırlamalara uymakla ayrıca yükümlüsünüz.

Kovid-19 salgını nedeniyle konulmuş olan kısıtlamaların yürürlükte olduğu süre içinde, tüm komite toplantıları elektronik ortamda yapılmaktadır; aşağıda isimleri bulunan Bilkent Üniversitesi Etik Kurulu Üyeleri adına bu yazıyı imzalama yetkisi kurul başkanındadır.

Etik Kurul Üyeleri:

Ünvan / İsim	**Bölüm / Uzmanlık**	
Prof.Dr. H. Altay Güvenir	Bilgisayar Mühendisliği	Başkan
Prof.Dr. Haldun Özaktaş	Elektrik ve Elektronik Müh.	Üye
Doç.Dr. Işık Yuluğ	Moleküler Biyoloji ve Genetik	Üye
Dr. Öğr. Üyesi Burcu Ayşen Ürgen	Psikoloji	Üye
Dr. Öğr. Üyesi A.Barış Özbilen	Hukuk	Üye
Prof. Dr. Özgür Ulusoy	Bilgisayar Mühendisliği	Yedek Üye
Dr. Öğr. Üyesi A.Barış Özçelik	Hukuk	Yedek Üye

Kurul karar/toplantı No: 2024_02_24_01 Başvuru No: 508

Bilkent Üniversitesi, 06800 Bilkent, Ankara • Telefon: (312) 290 12 13 • (312) 290 12 14 • Faks: (312) 266 41 52

Figure D1 Research Ethics Committee Approval

APPENDIX E. Additional Statistical Analysis

Table E1 *Cronbach's Alpha Reliability Analysis from Mean Data*

Mean Data: The Collaborative Learning Assessment		
Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0,82	0,829	7

Table E2 *Cronbach's Alpha Reliability Analysis from Individual Data*

Individual Data: The Collaborative Learning Assessment		
Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0,882	0,886	27

Table E3 *Fisher's Exact Test: VR Tool Experience Correlations*

	Value	Exact Sig. (2-sided)
Attitude	10,588	0,1
Confirmation	5,575	0,733
Satisfaction	10,007	0,133
Perceived Impact of Learning	5,797	0,763

Note. *Correlation is significant at the 0.05 level (2-tailed).

Table E4 *Fisher's Exact Test: Computer Program Experience Correlations*

	Value	Exact Sig. (2-sided)
Perceived Ease of Use	4,749	0,67
Perceived Usefulness	7,882	0,309
Attitude	5,586	0,702
Confirmation	7,448	0,476
Perceived Enjoyment	3,727	0,482
Satisfaction	5,327	0,792
Perceived Impact of Learning	6,136	0,871

Note. *Correlation is significant at the 0.05 level (2-tailed).

Table E5 *Fisher's Exact Test: Computer Design Program Experience Correlations*

	Value	Exact Sig. (2-sided)
Perceived Impact of Learning	8,997	0,238
Satisfaction	6,595	0,449
Attitude	3,654	0,985
Confirmation	5,07	0,671
Perceived Ease of Use	4,787	0,624
Perceived Usefulness	6,909	0,587
Perceived Enjoyment	3,925	0,479

Note. *Correlation is significant at the 0.05 level (2-tailed).

Table E6 *Fisher's Exact Test: Metaverse Experience Correlations*

	Value	Exact Sig. (2-sided)
Attitude	7,605	0,272
Perceived Ease of Use	4,325	0,694
Perceived Enjoyment	7,159	0,076
Satisfaction	6,931	0,411
Perceived Impact of Learning	10,05	0,167

Note. *Correlation is significant at the 0.05 level (2-tailed).