GRID ARCHITECTURE, PLANNING AND DESIGN JOURNAL
GRİD MİMARLIK, PLANLAMA VE TASARIM DERGİSİ

Vol. 8, No. 2, 2025, 435-457 / Cilt 8, Sayı 2, 2025, 435-457 / DOI: 10.37246/grid.1482382

Creating a hybrid environment via leap motion device for architecture students in digital age

Sevgin Aysu BALKAN[1], ORCID: 0000-0001-8695-3897
Arife KOCA[2], ORCID: 0000-0002-1739-1699

Keywords

Designing space; Design moves; Hybrid environment; Interactive tool; Leap motion

Abstract

Digital environments define alternatives to physical realities. The merging of virtual and real spaces creates a “cybernetic space” that offers a new experience through bodily interaction. This study explores the potential of hybrid design techniques to create new forms of representation at the intersection of body, physical space, and virtual space. It also highlights the importance of interactive design environments in supporting spatial learning in design disciplines. The scope of the research involves developing a hybrid architectural design software based on gesture interaction that supports learning-by-doing in digital environments. A practice-based research methodology was adopted. Scenario-based evaluations were conducted through self-guided sessions where the researcher explored the functionality and experiential aspects of the system. Leap Motion—a device equipped with infrared cameras and sensors that captures hand gestures—was employed to enable intuitive interaction with three-dimensional architectural models. The findings suggest that such hybrid systems can enhance spatial awareness and encourage a body-based design experience in architectural education.

Article Information

Received:
11.05.2024

Received in Revised Form:
11.06.2025

Accepted:
24.06.2025

Available Online:
28.10.2025

Article Category

Research Article

Highlights

- A hybrid design environment is proposed to combine the hand-eye coordination development of the physical model and the practicality of the digital model.
- It is emphasized that cybernetic spaces, which are a combination of virtual and real spaces, can offer new experiences.
- It is highlighted that architectural representation environments are very effective in the design process.

Contact

1. Department of Architecture, Eskişehir Technical University, Eskişehir, Türkiye

aysuoryasin@gmail.com

2. Department of Architecture, Eskişehir Technical University, Eskişehir, Türkiye

arifekoca1@gmail.com

Balkan, S.A. & Koca, A. (2025). Creating a hybrid design environment via leap motion device for architecture students in digital age. *GRID Architecture Planning and Design Journal,* 8(2), 435-457.

GRID ARCHITECTURE, PLANNING AND DESIGN JOURNAL
GRİD MİMARLIK, PLANLAMA VE TASARIM DERGİSİ

Vol. 8, No. 2, 2025, 435-457 / Cilt 8, Sayı 2, 2025, 435-457 / DOI: 10.37246/grid.1482382

Dijital çağda mimarlık öğrencileri için leap motion cihazı ile hibrit tasarım ortamı önerisi

Sevgin Aysu BALKAN[1], ORCID: 0000-0001-8695-3897
Arife KOCA[2], ORCID: 0000-0002-1739-1699

Öz

Dijital ortamlar, fiziksel gerçekliklerin alternatiflerini tanımlamaktadır. Sanal ve gerçek mekânın birleşimiyle oluşan "sibernetik mekân", bedensel etkileşimle yeni bir deneyim ortamı oluşturmaktadır. Bu çalışma, beden, fiziksel çevre ve sanal mekânın kesişiminde hibrit tasarım tekniklerini kullanarak yeni temsil biçimleri üretme potansiyelini araştırmaktadır. Ayrıca etkileşimli tasarım ortamlarının, tasarım disiplinleri için mekânsal öğrenmeyi güçlendirmede taşıdığı öneme dikkat çekmektedir. Araştırmanın kapsamı, dijital ortamlarda yaparak öğrenmeyi destekleyen, jest tabanlı etkileşime dayalı hibrit bir mimari tasarım yazılımının geliştirilmesini içermektedir. Uygulamaya dayalı (practice-based) bir araştırma metodolojisi benimsenmiştir. Senaryo tabanlı tasarım değerlendirmesi için araştırmacının kendi kullanım durumlarını içeren öz-yönlendirmeli oturumlar gerçekleştirilmiştir. Bu süreçte el hareketlerini algılayan ve sezgisel bir şekilde üç boyutlu mimari modellerle etkileşim kurulmasını sağlayan Leap Motion cihazı (kızılötesi kameralar ve sensörlerden oluşan bir cihaz) kullanılmıştır. Bulgular, bu tür hibrit sistemlerin mekânsal farkındalığı artırabileceğini ve tasarım eğitiminde bedene dayalı bir tasarım deneyimi geliştirebileceğini ortaya koymaktadır.

Anahtar Sözcükler

Mekan tasarımı; Tasarım hareketleri; Hibrit tasarım ortamı; Etkileşimli cihazlar; Leap motion

Makale Bilgileri

Alındı:
11.05.2024

Revizyon Kabul Tarihi:
11.06.2025

Kabul Edildi:
24.06.2025

Erişilebilir:
28.10.2025

Makale Kategorisi

Araştırma Makalesi

Öne Çıkanlar

- Maketin el-göz koordinasyonunu geliştirici özelliğini ve dijital modelin pratikliğini birleştirecek hibrit bir tasarım ortamı önerilmiştir.
- Sanal ve gerçek mekan birlikteliğinde oluşan sibernetik mekanların yeni deneyimler sunması potansiyeli üzerinde durulmuştur.
- Mimari temsil ortamlarının tasarım sürecinde oldukça etkili olduğu vurgulanmıştır.

İletişim

1. Mimarlık Bölümü, Eskişehir Teknik Üniversitesi, Eskişehir, Türkiye

aysuoryasin@gmail.com

2. Mimarlık Bölümü, Eskişehir Teknik Üniversitesi, Eskişehir, Türkiye

arifekoca1@gmail.com

Balkan, S.A. & Koca, A. (2025). Dijital çağda mimarlık öğrencileri için leap motion cihazı ile hibrit tasarım ortamı önerisi. *GRID Mimarlık Planlama ve Tasarım Dergisi,* 8(2), 435-457.

1. INTRODUCTION

From the early years of formal education in architecture, physical prototypes have been created, and abstract ideas have been tried to be embodied with three-dimensional representations (Dunn,2014). Three-dimensional models for the discipline of architecture can be considered as a means of exploration to express the design idea and reveal its potential in the early stages of design. Aspects of revealing design intention and supporting expressivity and intuitive thinking are also an important part of the design process. With the development of design tools along with technology, creative design processes are also evolving (Sanders 2013). In the conceptual design phase, changing and transforming the produced models helps to produce different design alternatives (Knoll & Hechinger, 2008). In the conceptual design phase, digital tools are used to provide cognitive stimulation and experience. Studies indicate that the use of these tools will be beneficial in the development of multisensory design methods (Zboinska, 2019; Sun, Wu & Cai 2019; Taşlıoğlu, 2018; Treadaway, 2009; Vertegaal & Poupyrev, 2008).

With the use of digital technologies, new tools and methods are being developed for architectural virtual environments. The benefits of digital models such as practical editing, detailed work and visualization of design from different angles lead to its widespread use today (Ibrahim & Rahimian, 2010). According to the research of Chen, Hsiao, & She (2015), it is shown that dynamic three-dimensional representations contribute to creativity. In this context, an effective digital design system should preferably be dynamic and allow a multisensory interaction in digital and physical form (Zboinska, 2019). It is stated that designing with new methods hybridizing with digital will contribute to reveal the potentials of design (Bermudez, 1997; Anderson et al., 2003; Reffat & Arabia, 2007; Turan, 2011).

Nowadays, technology and experience come together in virtual environments where the subject and the digital environment overlap (Walker, 1990). Virtual technologies have developed in recent years and are mostly used in the entertainment industry. There are studies on the beneficial effects of integrating virtual environments into the design process (Reffat, 2005; Kalisperis et al, 2002). While the practical use of digital tools for design disciplines is increasing day by day, design education cannot keep up with this differentiation at the same rate. The use of virtual reality and dynamic technologies in three-dimensional design methods has not yet become widespread (Özgen et al. 2021). Studies show that the sooner designers encounter digital tools, the faster they can adapt (Ibrahim & Rahimian, 2010; Varinlioğlu, Alaçam & Halıcı, 2015)

Recent studies have increasingly explored the use of Leap Motion and gesture-based interactions in architectural design and hybrid learning environments. Dong (2024) highlights the transformative potential of XR technologies and interactive systems in design process. Gao et al. (2024) proposed a design framework for touchless gesture-based interaction systems, demonstrating improvements in user experience. Nguyen et al. (2025) showed that comprehensible architectural gestures for robotic furniture can be developed through collaborative design, revealing the adaptability of Leap Motion in architectural systems. Similarly, Johnson and Saniie (2023) demonstrated how Leap Motion can be used to develop gesture-based user interfaces that operate across multiple interconnected systems, enabling seamless human interaction in complex digital environments. Dülgeroğlu and Yılmaz (2022) reported that Leap Motion enhances spatial awareness and supports intuitive manipulation in architectural design education, while also pointing out certain limitations in gesture recognition accuracy. Likewise, Falcao et al. (2015) evaluated the use of Leap Motion in graphic design applications and highlighted issues such as gesture recognition errors, lack of feedback, and user fatigue.

Based on these findings, this study does not use Leap Motion merely as a tool for digital input but also proposes it as an environment that supports spatial learning. It extends previous definitions of hybrid environments by defining hybridity as a cognitive and experiential process that integrates hand–eye coordination, intuitive modeling, and spatial awareness. This approach provides a holistic and embodied learning model, particularly relevant to early-stage architectural design education. Based on reviewed studies and approaches, this study aims to propose a new three-dimensional design environment by supporting the designer's experience with physical models through digital tools. In this context, it is important not to lose the benefits of the physical model like eye-hand coordination, activation of perception and its transformation into experience. An innovative design environment proposal was created by evaluating the advantages and disadvantages of traditional and digital environments. This study adopts a design research approach, more specifically a practice-based methodology. The development of the proposed hybrid interface involves an iterative process that includes conceptual framework creation, prototyping, and scenario-based design evaluations. The process includes the researcher's own use cases to test functionality, usability, and spatial interaction experience. The Leap Motion-based hybrid environment was developed using a user-centered design approach, where interaction, feedback, and spatial layout were improved through practical testing. This approach is similar to early experimental studies often seen in human-computer interaction (HCI) and digital design education. Within the scope of the study, new production potentials with digital methods have been proposed by preserving the advantageous situations regarding three-dimensional thinking and production practices. This early-stage application thus serves as a preliminary artifact, offering a foundation for future empirical studies, particularly in architecture and design education.

2. PRODUCING AND PERCEIVING SPACE IN THE DIGITAL AGE

Architectural representation is not merely a visual means of transmission; it constitutes a multilayered relationship between perception, experience, and cultural continuity (Vesely, 2004). Digital tools transform this relationship by reshaping how design is perceived and by introducing a new understanding of materiality (Picon, 2010). This transformation marks the rise of a hybrid culture in architecture, which Carpo (2017) describes as the "second digital turn." Leach (2009) and Menges (2012) argue that this digital shift is not just a formal innovation but a paradigmatic change that opens new spatial possibilities. Colomina (1996; 2019), from a media theory perspective, explores how digital media redefines the body and the boundaries between public and private space.

Three-dimensional representations serve as one of the most effective ways to directly establish a connection between perception and the body within the design process. Zevi (1957) emphasized that two-dimensional representations such as plans, sections, and elevations may fail to fully convey or generate space, whereas three-dimensional, bodily-involved experiences enrich spatial perception. At this point, technology becomes not only a tool but also an extension of the human body (McLuhan, 1964). As these technological components integrate with the body, both space and experience are transformed through their mutual interaction.

New information and communication technologies are transforming not only architectural design but also everyday life, learning methods, and interaction practices (Wiltse & Stolterman, 2010). According to McLuhan (1994), each new communication technology creates its own environment. In this context, technology emerges as a decisive factor in shaping the interaction between individuals, society, and space. Today, technological tools do not only alter how we interact but also redefine the very nature of experience itself. This transformation opens up new possibilities in how spatial awareness and perception are developed.

In parallel with this transformation, the concept of experience design gains importance. Sanders (2006) emphasizes that beyond traditional tools, experience environments developed through interactive technologies and new media platforms have the potential to reshape both perception and action. Technologies such as virtual reality offer new types of experience in which, although the physical body is not transferred into the virtual environment, motor skills are still engaged, and a form of mental embodiment through sensory channels becomes possible. This condition leads the body to transcend temporal and spatial boundaries, evolving into a more fluid form. Mitchell (1995) points out that in such environments, the perception of virtual and physical objects may begin to converge, suggesting that in the future, digital technologies will generate alternative realities within digital space.

Considering these theoretical perspectives, the gesture-based hybrid design environment proposed in this study is not merely a technical system that combines digital and physical components. Rather, it serves as an experiential manifestation of the transformations discussed above. It offers a critical framework for rethinking how space is defined in the digital age—where space is no longer a static object but an interactive process in which the user becomes both a perceiving and acting subject.

2.1. Representation of Space in Architectural Education in the Digital Age

The expression of an object or a place through representations occurs through cognitive processes between the representation and its producer. The lines produced by a designer during the design process are records of the relationships between the components and stages of an evolving design (Linzey, 2001). Architectural representations have the power to direct and reinterpret architectural practice as well as expressing thought. In addition, it can be states that it creates a new reality that plans the objects and the process (Akın, 1986). It is necessary to emphasize that besides being a technical phenomenon, it also has a social and cultural aspect (Gürer & Yücel 2005). In summary, architectural representations reflect the mind of the designer from the educational stage and are influenced by current conditions. In contemporary discourse, representation is not only a reflection of thought but a performative and generative act that enables the production of spatial knowledge (Oxman, 2008; Celani & Vaz, 2021).

In architectural education, learning by doing method, which consists of thinking, doing, producing skills and knowledge, is used. Learning by experiencing and doing, which is the basis of architectural education, makes design education special by enabling the individual to think in a creative way (Dutton, & Willenbrock, 1989). In the creative design process, sketches and drawings are used as well as representations that encourage three-dimensional thinking such as digital models and physical models. The increasingly complex programs and contents in the discipline of architecture create differentiations in terms of design ideas (Schnabel, 2004; Abdelhameed, 2013). The tools used in transforming the idea into a design are decisive on the design process and the outcome. Isozaki & Asada (1999) mention that all the thoughts in our minds are animated, like computer graphics, during the design process. It has been stated that the images in our minds are being developed with the feedback received from the represented in order to generate new possibilities. With the integration of immersive tools such as VR and AR, students do not only visualize space, but also inhabit it cognitively, which enhances experiential learning and decision-making (Pellas et al., 2020).

Working with a physical model during the conceptual design phase improves the student's three-dimensional thinking skills and enables them to grasp the object-body relationship. Physical model making enables the formal and spatial qualities of a design (form, size, color or material, etc.) to be explored. Dunn (2014) expressed the model as a way of establishing creative process and visual relationships. The easily revised nature of the physical model aids in the search for design alternatives (Knoll & Hechinger, 2008). Physical models are also important in terms of perceiving the form and program of the space. In addition to being used as an expression of the finished space, it is a representation tool that shapes the architectural project and strengthens the spatial qualities (Maltzan, 2010). Architectural physical models are design tools that support communication and thinking between the designer and the design (Smith, 2004). The first stages of a design process are an experimental process in which the design idea is formed, and the qualities of the space are constructed (Zaman, 2011).

Norman (2001) states that the creation of new forms and the expression of complex imagination require the search for alternative forms of representation. It is stated that new pedagogical discoveries are needed by increasing the association of digital technologies with design studios (Oxman, 2006). Creating new digital ecosystems for architecture education and practice that are impacted by technological changes is crucial (Reffat & Arabia, 2007). The use of virtual environments provides an advantage in terms of eliminating the deficiencies of the systems in the design (Anderson et al., 2003). According to Cobb et al, (2002) virtual reality applications in architectural design studio can minimize the difference between design ideas and representation. New forms of representation may include many tools and methods that enable design to be experienced and imagined.

The use of computer aided design tools also finds its way into the architectural education curriculum. Its effect was not limited to design studios, but the entire architectural education curriculum was reshaped with technological tools (Soliman, Taha, & El Sayad 2019). Tschumi (2017) stated that the design tools developed with digital technologies fundamentally affect the design studio environment. Opportunities provided by digital technology tools go beyond creating sketches and appear as a new way of thinking for designers and architects. Design courses focused on technology were added to formal architectural education. The number of courses in parallel with technological developments and their intensity in the curriculum are increasing. As digital ecosystems become more integrated into studio culture, representation shifts from being a product of drawing to a multisensory interface—incorporating gesture, simulation, and feedback in real time (Soto & Miller, 2023).

Both physical and digital models have advantages and disadvantages. The two models have missing points when it comes to perceiving and experiencing space. In view of the current technological conditions, it is necessary to find new techniques which minimize disadvantages (Segers et al., 2000). Producing hybrid design methods by combining beneficial situations from virtual environments and physical models will improve design processes. The design actions carried out at these stages are increasingly being transferred to the digital environment. In hybrid design settings, bodily engagement with digital environments—such as motion-based interactions—facilitates embodied spatial understanding and enhances perception of scale and form (Milovanovic et al., 2021; Du & Clayton, 2022).

2.2. Virtual Environments and Hybridization for Architectural Education

The interaction between environments changing from reality to virtuality defines alternative spaces. The digital space created by virtual and real space in connection with each other is called 'cybernetic space' (Mitra & Schwartz, 2001). Novak (1991) describes the transition between spaces as "the transition from real space to cyberspace... the transition from static to dynamic, from passive to active, from all fixed forms to changeable surfaces". Recent studies emphasize that cybernetic spaces are not only digital overlays but are entangled systems where perception, action, and computation occur simultaneously in architectural experience (Kolarevic & Parlac, 2021). Cybernetic space has the potential to provide an experience environment by creating a new interface with the interaction of space and body.

Cybernetic interactions in the digital environment form a hybrid design environment, not by being directly connected to space, but by blending into space. Schmitt (2001) defines hybrid as the relationship between space and body that generates a new order through digital relationships. Hybrid environments extend architectural thinking beyond the visual, enabling designers to engage with spatial cognition through embodied interactions and responsive feedback systems (Soto & Miller, 2023). The body creates a new dimension for itself between real space and virtual space. Experiencing the body provides the opportunity to imagine different spaces (Palumbo, 2000). This process reflects a shift from representational embodiment to performative embodiment, where the body becomes a site of real-time negotiation between physical materiality and digital abstraction (Du & Clayton, 2022).

The combination of physical and virtual environment creates an ideal environment for the designer to communicate and interact with spatial ideas. It is important to develop a new environment proposal that can produce cybernetic spaces by using "hybrid" design techniques in the design process by supporting physical models with digital tools. In the study, new production potentials are discussed by using digital methods at the intersection of physical and virtual environment. This study focuses on a three-dimensional design environment developed for architecture and design disciplines. The system was created using the Leap Motion device, which supports hand-eye-mind coordination and enables digital-physical mixed reality. Motion-tracking technologies like Leap Motion have recently been adopted in architectural pedagogy to promote spatial learning through gestural input and embodied interaction, forming the basis of mixed reality studios (Milovanovic et al., 2021). Cameras and infrared rays in Leap Motion detect the movement in our hands and enable cybernetic experience. A sensation is created at the intersection of the body, physical space and virtual space. It is aimed to develop a "new" space experience by using hybrid design techniques within the event-action pattern. Such hybrid spatial experiences resonate with current trends in architecture where space is no longer a fixed container, but a responsive system shaped by bodily movement, environmental feedback, and computational logic (Schnabel, 2020).

3. GESTURE – BASED DESIGN: HYBRID ARCHITECTURAL MODEL ENVIRONMENT PROPOSAL PRODUCED WITH LEAP MOTION

With the development of new interfaces and new human-computer interaction possibilities, the network of cybernetic space has become a natural part of daily life (Jacob, 1994). Especially with the development of natural interfaces, the possibility of cybernetic interaction transforms the way of perceiving the world and generating thoughts. Natural user interfaces are the general name of technologies provided by the natural movements of the body and computer interaction (Hearst, 2011). In these interfaces, cybernetic interaction is provided by speaking, looking, touching and various body movements. The use of interactive design and visualization technologies in the architecture discipline is becoming more common. Goh, Sunar, and Ismail (2019) state that three-dimensional object interactions can be categorized into three distinct types. These are classified as touch-based interaction, air gesture-based interaction and device-based interaction. As stated in Figure 1, the Leap Motion device provides interaction based on movements in the air. The Leap Motion device is defined as a sensor that aims to convert hand movements into computer commands and is used for human interaction with computer systems through gestures (Tölgyessy et al, 2023). Treadaway (2009) discusses the role of hands in creative activity, especially when working in digital environments. Studies show that hands act as a communication tool that conveys the designer's memories and experiences of the design process. In addition, according to the study of Treadaway (2009), the hands not only enrich this experience and interaction, but also increase the sensory interaction and allow multiple senses to be included in the design process.

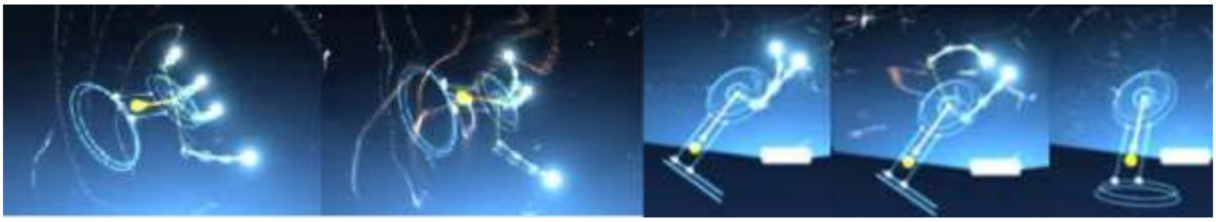

Figure 1. Transferring hand gestures to computer environment with leap motion (Ohol et al, 2017)

The Leap Motion device allows advanced gesture-based interaction due to its highly sensitive hand and finger tracking capability (Korayem et al., 2021). It detects the area on it by the controller positioned on a surface and is sensitive to a range of approximately one meter (Potter et al., 2013). There is an IR camera and three infrared LEDs on the device, which observes a hemispherical surface. The infrared motion sensor inside the Leap Motion device has software that detects and identifies the joints in the hand. It helps to use the computer without touching anything by detecting movements up to a height of about one meter with the infrared cameras in the device, which are connected to the computer via USB connection and can shoot at 200 frames per second (Escobar, 2018). It has been produced as an alternative to conventional computer input devices such as keyboard and mouse used nowadays. It is intended to involve the user more in computer control with hand - finger movements. The data sent as homogenous matrices describe the position and orientation of the hand joints.

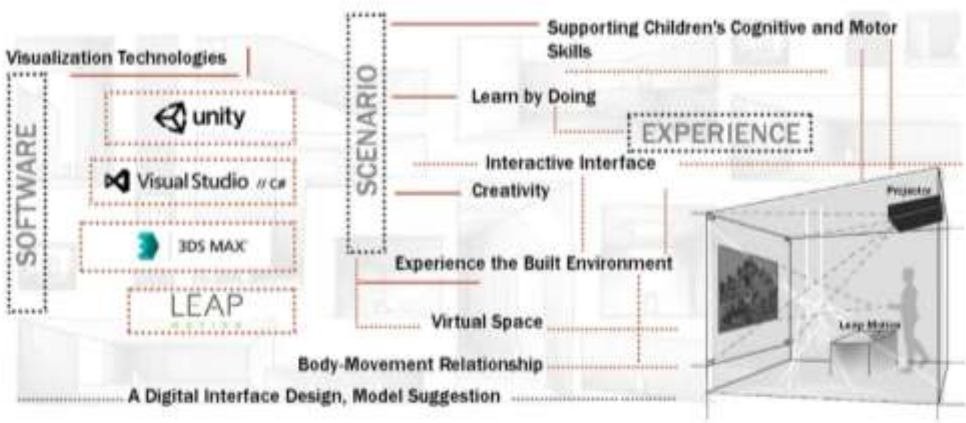

Figure 2. Diagram describing the development process of the created model.

The device, which defines a system that facilitates human-computer interaction, includes additional controls to conventional methods. With the help of natural user interfaces shaped by body movements (Hearst, 2011), instead of commands such as clicking and touching, it enables the desired action to be performed by interacting with the computer environment without touching anywhere. This method improves hand-eye coordination and muscle memory with cognitive and interactive learning components. It also defines a cybernetic environment by attempting to establish the interaction between reality and virtual with technological methods. The cybernetic environment tends to create a dynamic space that can change depending on the current interaction. It is used as a tool to reflect the dynamic structure of the design to space. The software used to create this tool and the way it works are shown in Figure 2. Within the scope of this study, the potential of the Leap Motion device to create an alternative to conventional tools was evaluated to facilitate the understanding of space by users. Given the evolving experiences of the younger generation raised with technology, this study is expected to make a meaningful contribution toward its intended objectives.

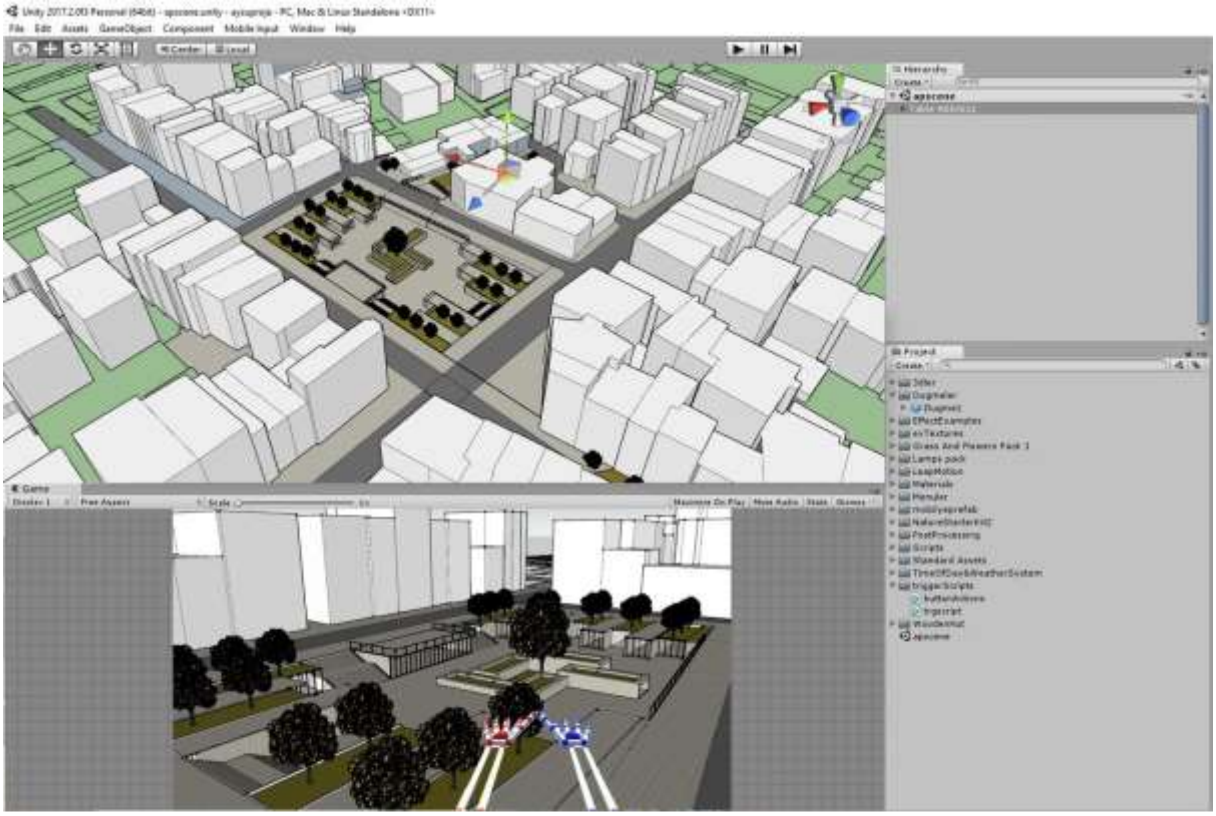

Figure 3. Imaginary urban setup designed with 3ds Max and Unity 3D software.

First, an imaginary urban space was designed within the scope of the proposed digital environment. The basic setup of this urban space was created in the 3ds Max (Figure 3). The software has been developed to allow users to experience and understand this urban space. The open-source program Unity 3D was used in the development of the urban design setup, providing mobility (commands such as pushing, pulling) and working in coordination with the Leap Motion device (Figure 2). While models can be made in Unity 3D, objects designed in other modeling programs can be used after they are converted into appropriate formats. A library has been created that the user can use while designing urban spaces. Unity 3D, which usually interacts with programming languages such as C# and Java, offers features such as providing visualization, enabling movement, and adding sound effects to objects. After the models were created in the study, a scene was constructed in Unity 3D. The modeled imaginary urban design consists of green spaces, buildings of various sizes and qualities, nodes and urban spaces. The model was provided to help users relate to the scale and context by recognizing that they are situated within a specific environment. Urban spaces define areas where the user can design using environmental data. In short, the template includes the items already provided and the areas left to the users for the design.

Vol. 8, No. 2, 2025, 435-457 / Cilt 8, Sayı 2, 2025, 435-457 / DOI: 10.37246/grid.1482382

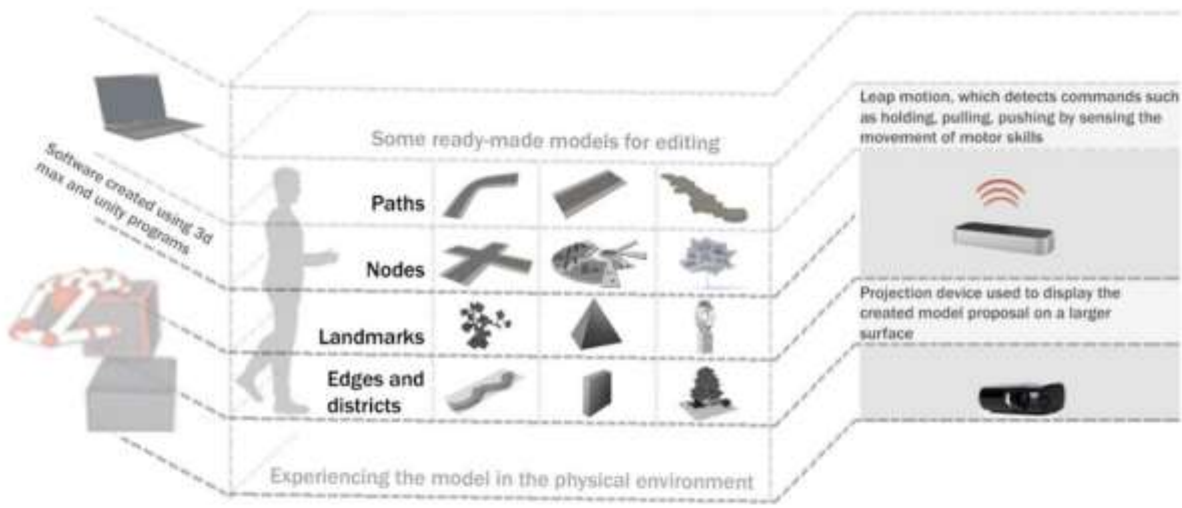

Figure 4. The diagram showing the surface-device-user relationship of the created model.

Lynch (1964) says that space should be permanent in the memory and emphasizes that the spaces should be in integrity. It reveals which urban elements are used while describing the environment. According to Lynch (1964), the appearance and memorability of cities are categorized into five basic visual perception elements: paths, edges, districts, nodes, and landmarks. In the study, five basic elements of visual perception were considered while providing the materials. The materials produced for the model include different types of paths, edges, districts, nodes, landmarks, structures of different forms and sizes, and trees of various sizes and types (Figure 4). It is aimed to understand how to perceive the design problem and how to develop a design approach to this situation. The role of urban architectural elements in design (paths, edges, districts, nodes, landmarks etc.) and the dimensions of the intervention express the perspective of the user. Furthermore, the relationship between the specified environmental conditions and the design context is among the topics addressed in the proposed model.

In the initial phase of the study, self-guided exploration sessions were conducted to evaluate the functionality and experiential aspects of the proposed hybrid environment. Using a Unity-based urban model integrated with the Leap Motion interface, fundamental interaction tasks such as grabbing, rotating, scaling, and navigating between spatial elements were tested. These sessions enabled a preliminary assessment of gesture recognition accuracy, interaction fluidity, and system responsiveness. Initial findings revealed occasional inconsistencies in gesture interpretation, particularly during complex hand movements. Despite this limitation, it was observed that the immediate feedback provided by gesture-based interaction enhanced the user's engagement with the system. Moreover, the active use of hands contributed to a multisensory experience that included not only visual but also tactile and kinesthetic perceptions. These findings made significant contributions to the refinement of the system and the improvement of interaction design.

4. DISCUSSION

4.1. Rethinking Spatial Design: A Comparative Overview of Traditional, Digital and Hybrid Environments

The characteristics of traditional and digital presentation environments are very different. The advantages and disadvantages of these environments shape the user experience and guide the process of spatial design. While traditional environments allow for physical interaction and sensory experiences, digital environments offer spatial independence and flexibility. Traditional environments stand out with the advantages of easy comprehensibility and quick feedback provided by face-to-face communication. Users can have a more tangible experience by having direct contact with projects or products. In digital environments, this situation can be considered as a negative aspect. Lack of face-to-face interaction can lead to difficulties in communication between users. However, traditional environments also have disadvantages such as transportation costs, the loss of time, and the need for physical space. In particular, difficulties in material access and limitations in production processes can make traditional environments lack flexibility. Digital environments are advantageous in terms of being accessible from anywhere and not having transportation problems. In addition, the fact that projects can be recorded and accessed again is a positive aspect that supports education and design processes. The positive and negative aspects of traditional, digital and hybrid design environments are discussed in the table.

Table 1. Comparison of traditional, digital and hybrid environments

Traditional Environments	
Positive(+)	Easy understanding through face-to-face interaction
	Direct contact between user and product/project
	Easy comprehensibility and quick feedback
	To be able to see directly the size, shape, color, texture in the real world
Negative(-)	Transportation costs
	Physical space needs (classroom, office, etc.)
	Material access and production challenges
Digital Environments	
Positive(+)	Being independent of space and time
	Opportunity to reach a wider audience
	Recordable and re-accessible
	Experiencing and imagining the design with virtual reality applications
Negative(-)	Lack of face-to-face interaction
	Technical problems (internet outage, hardware problems, etc.)
	Lack of physical activity
	Feeling socially isolated
	Difficulty perceiving the scale-ratio relationship with the physical environment
Hybrid Environments	
Positive(+)	Combines the advantages of physical and digital design
	Enhances spatial perception through gesture-based interaction
	Supports embodied and intuitive learning
	Enables rapid prototyping through physical coordination
	Engages visual, kinesthetic, and cognitive senses
	Encourages creative exploration through trial and error
	Establishes scale and proportion through bodily feedback
	Balances face-to-face interaction with remote accessibility
Negative(-)	Requires specific hardware and software (e.g., Leap Motion, Unity 3D)
	Provides limited tactile feedback compared to physical models
	Gesture recognition errors may affect user experience
	Prolonged use may cause gesture fatigue
	Technical knowledge may be required to operate the interface
	Not yet widely implemented in architectural education

Guided by the mentioned positive and negative aspects of the digital and traditional environment, a hybrid design tool has been suggested within the scope of this study. The infrastructure of the hybrid environment proposal consists of the data in the table. It is aimed to provide a more flexible solution by combining the strengths of both approaches. In the proposal, the perception of scale and proportion was tried to be strengthened. In addition, the study aims to support imagination through trial and error by using the rapid production potential of virtual environments. Beyond merging the advantages of the two environments, this approach also responds to the evolving pedagogical requirements of the digital age. It seeks to establish a new learning space in which students can simultaneously develop intuitive and technical design skills.

The integration of gesture-based control enables users to become not just observers but active agents of spatial production. In this respect, hybrid environments activate both bodily awareness and cognitive processes (Norman, 2013; Kolarevic, 2003). This direction aligns with recent theoretical perspectives emphasizing the transformation of design pedagogy and cognition through digital technologies. Colomina (2019) and Picon (2021), for example, argue that digital tools reshape not only architectural representation but also the very processes through which we think and learn about space. The hybrid tool developed in this study, with its gesture-responsive interface and rapid prototyping capability, supports creative problem-solving and design thinking processes essential to contemporary education. Ultimately, the proposed system does not merely offer a technological solution but a conceptual framework that redefines design interaction in line with emerging cognitive and educational needs.

4.2. Literature-Based Comparative Discussion

This study proposes an original hybrid design environment that combines the perceptual power of physical modeling with digital design tools. The developed system reintegrates bodily engagement into the design process, particularly through gesture-based interaction enabled by Leap Motion. In this sense, it differs from traditional modeling tools that rely solely on visual representation in digital environments. The positive and negative aspects of traditional and digital design environments were analyzed in the study, forming the basis of the proposed hybrid tool. By combining the strengths of both approaches, the hybrid solution aims to offer greater flexibility. The tool enhances perception of scale and proportion and supports imagination through trial-and-error using the rapid production potential of virtual environments.

For instance, Schubert et al. (2015) emphasizes the ergonomic benefits of digital control through Leap Motion yet focuses less on its contributions in educational contexts. In contrast, the interaction experiences in this study demonstrate that the system enhances intuitive learning in design education. The study by Tang et al. (2016) focuses on the technical capabilities of Leap Motion in the context of digital architecture but pays limited attention to the connection between bodily experience and conceptual design. This research, however, brings the effects of physical modeling on hand-eye-mind coordination into the digital realm, thereby supporting spatial awareness and three-dimensional thinking. Similarly, Falcao (2015) discusses the impact of digital fabrication tools on spatial configuration but does not extensively address the pedagogical dimension of interactive systems. This study highlights the potential of hybrid environments in both experiential and pedagogical dimensions of design education. Furthermore, Falcao (2015) emphasizes the importance of supporting digital tools with bodily experience. The developed software in this study offers a novel contribution by enabling simultaneous experiences of touch, hearing, and vision in a digital environment.

Technology and spatial experience converge in virtual environments where the subject and the digital setting intersect to create immersive design processes (Walker, 1990). Although the use of such environments remains limited, their application has expanded across diverse fields such as informatics, entertainment, and engineering (Billinghurst & Kato, 2002). Recent literature indicates a growing interest in utilizing virtual environments within design disciplines, especially for enhancing interaction and experimentation. Zboinska (2019) argues that effective digital design systems should be dynamic and support multi-sensory interaction, merging digital and physical experiences. Building on these principles, the present study introduces a hybrid design software that enables multi-sensory engagement by integrating visual, tactile, and auditory stimuli within a digital platform. Developed through Unity 3D and operated via Leap Motion, the system facilitates gesture-based interaction, reinforcing hand-eye-mind coordination throughout the design process. Furthermore, the conceptual framework developed by Lynch (1964) on spatial perception was referenced in the design of the software's user interface, aiming to support spatial experience at a cognitive level as well. Although the tool has not yet been tested in an educational setting, it functions as a preliminary prototype for future studies aimed at improving digital tools in design pedagogy.

4.3. Self-Guided Usability Reflections and Limitations

In this study, the initial evaluation of the system was conducted through individual user sessions performed by the researcher. These exploration-based sessions demonstrated the system's functionality in translating early design ideas into digital spatial representations. The intuitive nature of gesture-based control supported body–mind coordination and enabled a more holistic engagement in the design process. However, the lack of tactile feedback was identified as a significant limitation. Compared to physical models, the digital environment offered a more abstract interaction experience, which led to difficulties in intuitively grasping certain spatial decisions. In this context, Dülgeroğlu and Yılmaz (2020) also point to the negative impact of digital design environments that lack tactile elements on user experience. Nonetheless, the gesture-based controls in the proposed system partially compensated for this limitation through real-time visual feedback and coordinated interaction. In parallel with Ishii and Ullmer's (1997) concept of "tangible user interfaces," this study proposes a method that prioritizes bodily engagement in the production of digital space.

Given that the evaluation process was based solely on the researcher's experience, the findings are not intended to be generalizable. However, they provide a qualitative example of how researcher-led experiences can be functional in early-stage prototype development. Similarly, Gaver (1991) argues that personal experience is a valuable tool in the early exploration and interpretation phases of design research. In future studies, systematic user testing with student participation will allow for more comprehensive evaluations in terms of pedagogical effectiveness, intuitive use, and design outcomes. In this way, the system can be developed not only as a technological tool but also as a learning environment that supports experiential and conceptual understanding in design education.

Vol. 8, No. 2, 2025, 435-457 / Cilt 8, Sayı 2, 2025, 435-457 / DOI: 10.37246/grid.1482382

5. CONCLUSION

Technological advances are changing the way of thinking and understanding. This change also provides paradigm shifts in terms of production and perception of space in the new age. Virtual spaces differentiate our perception of reality and make it inevitable to create new relations between body and mind. Up to recently, virtual environments could be expressed as areas where the body could not be transferred because of technological interfaces and only the mind was a priority. However, in today's conditions, new discussion topics arise between virtual - real space and body, with the transfer of our body movements and our senses to the virtual environment, thanks to natural user interfaces. The perception enriched with digital interfaces points to a hybridization between abstract and concrete spaces. Hybridized spaces and interfaces create a new fluidity between new body-space experiences and digital-analog environments in today's digital world. The senses of space and body can merge and change into spaces that are enriched with action-reaction situations and have the quality of an organism in the future.

In the study, a design tool was created that forms the infrastructure of conceptual thinking and facilitates model making in the virtual environment. While there is a physical production in the traditional model, there is a virtual production without touching in the digital model. While the advantages of the physical model are learning by doing and the use of hand gestures, the digital model has applicability, rapid production and accessibility. The materials are required for the physical model, and in the digital model, materials are ready in the computer environment. At the intersection of physical and digital environment, a proposal for "a hybrid design environment software with Leap Motion device" has been developed. In future studies, the sense of reality of the environment to be experienced can be further increased by supporting it with cybernetic networks. This interface and usage of the device can be further developed and its potential enhanced.

This study offers an original contribution to the ongoing discourse on hybrid design environments by integrating bodily interaction with digital spatial design. It highlights the potential of intuitive, embodied tools to reshape architectural education and practice. The current version of the system functions as a demo prototype and has not yet been tested in a classroom setting. However, initial observations suggest that such hybrid environments can effectively complement traditional design studios within the context of increasingly digitalized education. Future studies are encouraged to conduct empirical tests with student groups and develop the interface iteratively based on usability data. In addition, broader interdisciplinary collaborations involving experts in education, design, and technology are recommended.

The digitalization process, which has accelerated with the Covid 19 epidemic, transforms architectural education. In the design studio process, which is one of the main actors of architectural design education, digital productions have increased with online courses. Physical models are no longer preferred for reasons such as access to materials and difficulties in production. While the architectural physical model is used as one of the ways to understand a space and establish it, 3D models have started to take its place. With the models produced in the computer environment, it becomes difficult to perceive the ratio-scale relationship with the physical environment or the relationship between topography-street-building. It is important to create and disseminate hybrid environments which can play an active role in learning processes and support new forms of experience.

Existing digital design environments are criticized in many ways, and different digital design tools that support creativity and that are not rigid are beginning to emerge with new technologies. With current technology, design tools and representation methods have a direct impact on the final product. The hybrid environment produced can be used in an interdisciplinary working environment with experts such as software developers, designers, educational scientists and architects. The proposed interface may become a design tool that will reflect students' imagination and help them develop original design approaches. It can bring a different perspective to the relationship between representation-experience-perception by contributing to the process of thinking-designing-production within the scope of architectural education and practice.

Acknowledgements | Teşekkür Beyanı

We would like to thank Önder Orakoğlu and Dr. Emir Balkan for their support in creating the software and using the Leap Motion device.

Conflict of Interest Statement | Çıkar Çatışması Beyanı

Araştırmanın yürütülmesi ve/veya makalenin hazırlanması hususunda herhangi bir çıkar çatışması bulunmamaktadır.

There is no conflict of interest for conducting the research and/or for the preparation of the article.

Financial Statement | Finansman Beyanı

Bu araştırmanın yürütülmesi ve/veya makalenin hazırlanması için herhangi bir mali destek alınmamıştır.

No financial support has been received for conducting the research and/or for the preparation of the article.

Ethical Statement | Etik Beyanı

Araştırma etik standartlara uygun olarak yapılmıştır.

All procedures followed were in accordance with the ethical standards.

Copyright Statement for Intellectual and Artistic Works | Fikir ve Sanat Eserleri Hakkında Telif Hakkı Beyanı

Makalede kullanılan fikir ve sanat eserleri (şekil, fotoğraf, grafik vb.) için telif hakları düzenlemelerine uyulmuştur.

In the article, copyright regulations have been complied with for intellectual and artistic works (figures, photographs, graphics, etc.).

Author Contribution Statement | Yazar Katkı Beyanı

AUTHOR 1: (a) Idea, Study Design, (b) Methodology, (c) Literature Review, (d) Supervision, (e) Material, (f) Data Collection, Processing, (g) Analyses, Interpretation, Resource Supply, (h) Writing Text, (i) Critical Review.

AUTHOR 2: (a) Idea, Study Design, (b) Methodology, (c) Literature Review, (d) Supervision, (e) Material, (f) Data Collection, Processing, (g) Analyses, Interpretation, Resource Supply (h) Writing Text, (i) Critical Review.

REFERENCES

Abdelhameed, W. A. (2013). Virtual reality use in architectural design studios: a case of studying structure and construction. *Procedia Computer Science, 25*, 220-230.

Akın, Ö. (1986). *Psychology of architectural design*. Pion, London.

Anderson, L., Esser, J., & Interrante, V. (2003). A virtual environment for conceptual design in architecture. *Proceedings of the workshop on virtual environments*, 57-63.

Bermudez, J., (1997), *Cyber(Inter)Sections: looking into the real ımpact of the virtual in the architectural profession*, Proceedings of the symposium on architectural design education: ıntersecting perspectives, ıdentities and approaches. Minneapolis, MN: College of Architecture & Landscape Architecture, 57-63.

Billinghurst, M., & Kato, H. (2002). Collaborative augmented reality. *Communications of the ACM*, *45*(7), 64-70.

Carpo, M. (2017). *The Second Digital Turn: Design Beyond Intelligence*. Cambridge, MA: MIT Press.

Celani, G., & Vaz, C. E. V. (2021). *Teaching digital design and fabrication in architecture: A review of pedagogical models*. Design Studies, 74, 101005.

Chen, S. C., Hsiao, M. S., & She, H. C. (2015). The effects of static versus dynamic 3D representations on 10th grade students' atomic orbital mental model construction: Evidence from eye movement behaviors. *Computers in Human Behavior*, *53*, 169-180.

Cobb, S., Neale, H., Crosier, J., & Wilson, J. R. (2002). Development and evaluation of virtual environments for education., *Handbook of virtual environments*, pp. 951-976.

Colomina, B. (1996). *Privacy and Publicity: Modern Architecture as Mass Media*. Cambridge, MA: MIT Press.

Colomina, B. (2019). *X-Ray Architecture*. Zürich: Lars Müller Publishers.

Dong, Y. (2024). *Expanding reality and interactive systems: New paths to hybrid design shaping the future of architectural designs*. International Journal of Education and Humanities, 17(2), 160–163.

Du, J., & Clayton, M. J. (2022). Effects of immersive virtual environments on spatial perception in architectural design education. *Automation in Construction, 139*, 104278.

Dunn, N. (2014). *Architectural modelmaking second edition*. Hachette UK.

Dutton, T. A., & Willenbrock, L. L. (1989). The design studio: an exploration of its traditions and potential. *Journal of Architectural Education, 43, 53-55.*

Dülgeroğlu, Y., & Yılmaz, G. (2022). *Investigating the use of Leap Motion controller in architectural design education: Students' experiences and spatial thinking skills*. International Journal of Technology and Design Education. https://doi.org/10.1007/s10798-022-09728-w

Escobar, I., Acurio, A., Pruna, E., Mena, L., Pilatásig, M., Bucheli, J., ... & Robalino, R. (2018). Fine motor rehabilitation of children using the leap motion device–preliminary usability tests. In *Trends and Advances in Information Systems and Technologies, 26,* 1030-1039.

Falcao, C., Lemos, A. C., & Soares, M. (2015). *Evaluation of natural user interface: A usability study based on the Leap Motion device*. Procedia Manufacturing, 3, 4359–4364. https://doi.org/10.1016/j.promfg.2015.07.697

Gao, W., Jin, S., Zhai, W., Shen, S., Tian, Y., & Zhang, J. (2024). *Study on the design of a non-contact interaction system using gestures: Framework and case study*. Sustainability, 16(21), 9335. https://doi.org/10.3390/su16219335

Gaver, W. W. (1991). *Technology affordances*. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 79–84. https://doi.org/10.1145/108844.108856

Goh, E. S., Sunar, M. S., & Ismail, A. W. (2019). 3D object manipulation techniques in handheld mobile augmented reality interface: A review. *IEEE Access*, *7*, 40581-40601.

Gürer, T. K., & Yücel, A. (2010). Bir paradigma olarak mimari temsilin incelenmesi. *İtü Dergisi/a*, *4*(1), 84-96.

Hearst, M. A. (2011). 'Natural'search user interfaces. *Communications of the ACM*, *54*(11), 60-67.

Ibrahim, R., & Rahimian, F. P. (2010). Comparison of CAD and manual sketching tools for teaching architectural design. *Automation in Construction*, *19*(8), 978-987.

Ishii, H., & Ullmer, B. (1997). *Tangible bits: Towards seamless interfaces between people, bits and atoms*. Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI ’97), 234–241. https://doi.org/10.1145/258549.258715

Isozaki, A., & Asada, A. (1999). Benzeştirilen köken, benzeştirilen son. *Anytime Conference Proceedings,* Mimarlar Derneği, Ankara.

Jacob, R. J. K. (1994). New human-computer interaction techniques. *Human Machine Communication for Educational Systems Design*, *129*, 131–138.

Johnson, H., & Saniie, J. (2023). *Distributed gesture controlled systems for human-machine interface*. arXiv preprint arXiv:2304.06152. https://doi.org/10.48550/arXiv.2304.06152

Kalisperis, L. N., Otto, G., Muramoto, K., Gundrum, J. S., Masters, R., & Orland, B. (2002). Virtual reality/space visualization in design education: the VR-desktop initiative. *Proceedings of eCAADe2002, design e-ducation: Connecting the Real and the Virtual*, 64-71.

Knoll, W., & Hechinger, M. (2008). *Architectural models: Construction techniques* (2nd ed.). J. Ross Publishing.

Kolarevic, B., & Parlac, V. (2021). *From Physical to Cyber-Physical: Architecture in the Age of Industry 4.0*. Routledge.

Korayem, M. H., Madihi, M. A., & Vahidifar, V. (2021). Controlling surgical robot arm using leap motion controller with Kalman filter. *Measurement*, *178*, 109372.

Leach, N. (2009). Digital morphogenesis. *Architectural Design*, 79(1), 32–37. https://doi.org/10.1002/ad.806

Linzey, M. (2001). On the secondness of architectural intuition. *Journal of Architectural Education*, *55*(1), 43-50.

Lynch, K. (1964). *The image of the city*. MIT press.

Maltzan, M. (2010). The model. Ed Michiel Riedijk, *Architecture as a craft: Architecture, drawing, model and position*. 197-213.

McLuhan, M. (1964). *Understanding media: The extensions of man*. London: McGraw Hill.

Menges, A. (2012). Material computation: Higher integration in morphogenetic design. *Architectural Design*, 82(2), 14–21. https://doi.org/10.1002/ad.1373

Merleau-Ponty, M. (2005). *Algılanan dünya* (4 b.). (Ö. Aygün, Trans.) İstanbul: Metis Yayıncılık.

Milovanovic, J., Gero, J. S., & Nakapan, W. (2021). The impact of immersive virtual reality on design cognition: A study in architectural education. *Design Studies, 74*, 101005.

Mitra, A., & Schwartz, R. (2003). From cyber space to cybernetic space: rethinking the relationship between real and virtual spaces. *Journal of Computer Mediated Communication.*

Nguyen, A. B. V. D., Leusmann, J., Mayer, S., & Vande Moere, A. (2025). *Eliciting understandable architectonic gestures for robotic furniture through co-design improvisation*. arXiv preprint arXiv:2501.01813. https://doi.org/10.48550/arXiv.2501.01813

Norman, F. (2001). *Towards a paperless studio*. Proceedings of the ARCC Spring Research Meeting Architectural Research Centers Consortium.

Novak, M. (1991). Liquid architectures in cyberspace. In *Cyberspace: first steps,* 225-254.

Ohol, A. Goudar, S. Shettigar, S. Anand, S. (2017) Touchless Touch Screen User Interface. *International Journal of Technical Research and Applications.* 43, 59-63.

Oxman, R. (2006). Theory and design in the first digital age. *Design studies*, *27*(3), 229-265.

Oxman, R. (2008). *Digital architecture as a challenge for design pedagogy: Theory, knowledge, models and medium*. Design Studies, 29(2), 99–120.

Özgen, D. S., Afacan, Y., & Sürer, E. (2021). Usability of virtual reality for basic design education: a comparative study with paper-based design. *International Journal of Technology and Design Education*, *31*, 357-377.

Palumbo, M. L. (2000). *New wombs: electronic bodies and architectural disorders*. Springer Science & Business Media.

Pellas, N., Fotaris, P., Kazanidis, I., & Wells, D. (2020). Augmented reality in education: Current trends and future directions. *Educational Technology Research and Development, 68*(6), 3045–3069.

Picon, A. (2010). *Digital Culture in Architecture: An Introduction for the Design Professions*. Basel: Birkhäuser.

Picon, A. (2021). Architecture and the digital: The environmental turn. In M. Salama, W. Wiedemann & N. Wilkinson (Eds.), *The Changing Shape of Architecture: Further Cases of Integrating Research and Design in Practice* (pp. 133–146). London: Routledge.

Potter, L. E., Araullo, J., & Carter, L. (2013). The leap motion controller: a view on sign language. In *Proceedings of the 25th Australian computer-human interaction conference: augmentation, application, innovation, collaboration*, 175-178.

Reffat, R. M. (2005). Collaborative digital architectural design learning within 3d virtual environments. *The 10th international conference on computer aided architectural design research in asia*.

Reffat, R.K., & Arabia S. (2007). Revitalizing architectural design studio teaching using ICT: Reflections on practical implementations *International Journal of Education and Development Using ICT 3(1).*

Sanders, E. B. (2006). Design research in 2006. *Design Research Quarterly*, *1*(1), 1-8.

Sanders, E. B. (2013). Prototyping for design spaces of the future. Ed L. Valentine, *In Prototype: Design and Craft in the 21st Century*, London: Bloomsbury Academic, 59–73.

Schmitt, G. (2001). Introduction, *Bits and spaces: architecture and computing for physical, virtual, hybrid realms: 33 projects by Architecture and CAAD*, ETH Zurich, Ed. Maia Engeli, Birkhäuser Publishers for Architecture, Basel, Boston, Berlin.

Schnabel, M. A. (2004). Architectural design in virtual environments. *(Doctoral Dissertation), University of Hongkong.*

Schnabel, M. A. (2020). The reformation of architectural education through mixed realities. *Architectural Design, 90*(1), 110–115.

Segers, N. M., Achten, H. H., Timmermans, H. J. P., & De Vries, B. (2000). A comparison of computer-aided tools for architectural design. *Design and decision support systems in architecture. Proceedings of the 5th International Conference*.

Smith, A.C. (2004). *Architectural model as machine: A new view of models from antiquity to the present day*, Elsevier.

Soliman, S., Taha, D., & El Sayad, Z. (2019). Architectural education in the digital age: Computer applications: Between academia and practice. *Alexandria Engineering Journal*, 58(2), 809-818.

Soto, D., & Miller, D. (2023). Bridging the gap: Mixed reality tools in early architectural design. *Technology|Architecture + Design, 7*(2), 145–157.

Sun, R., Wu, Y. J., & Cai, Q. (2019). The effect of a virtual reality learning environment on learners' spatial ability. *Virtual Reality*, 23(4), 385-398.

Taşlıoğlu, M. (2018). *Sibernetik Mekân Deneyimleri.* (Master's Thesis), İstanbul Technical University, İstanbul.

Tölgyessy, M., Dekan, M., Rodina, J., & Duchoň, F. (2023). Analysis of the leap motion controller workspace for HRI gesture applications. *Applied Sciences*, 13(2), 742.

Treadaway, C. P. (2009). Hand e-craft: an investigation into hand use in digital creative practice. In *Proceedings of the seventh ACM conference on Creativity and cognition*, (pp. 185-194).

Tschumi, B. (2017). Mimarlık ve kopma (1 b.). (A. Tümertekin, Trans.) İstanbul: Janus Yayıncılık

Turan, B. O. (2011). 21. Yüzyıl tasarım ortamında süreç, biçim ve temsil ilişkisi. *Megaron*, 6(3).

Varınlıoğlu, G., Halıcı, S., & Alaçam, S. (2015). *Computational approaches for basic design education: Pedagogical notes based on an intense student workshop*. In XIX congresso da sociedade ibero Americana de Gráfica Digital 2015.

Vertegaal, R., & Poupyrev, I. (2008). Organic user interfaces. *Communications of the ACM*, *51*(6), 26-30.

Vesely, D. (2004). *Architecture in the Age of Divided Representation: The Question of Creativity in the Shadow of Production*. Cambridge, MA: MIT Press.

Wiltse, H., & Stolterman, E. (2010). Architectures of interaction: An architectural perspective on digital experience. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, 821-824.

Zaman, Ç. H. (2011). *A hand motion-based tool for conceptual model making in architecture* (Doctoral dissertation) İstanbul Technical University. İstanbul.

Zboinska, M. A. (2019). Influence of a hybrid digital toolset on the creative behaviors of designers in early-stage design. *Journal of Computational Design and Engineering*, *6*(4), 675-692.

Zevi, B. (1957). *Architecture as space: How to look at architecture* (M. Gendel, Trans.). New York.

BIOGRAPHIES OF THE AUTHORS

Sevgin Aysu BALKAN

Sevgin Aysu Balkan has a Bachelor's degree (2015) on Architecture and a master's degree on Architectural Design (2019) at Anadolu University. She attended Erasmus exchange program in Universidad Eurepea de Madrid, Spain, in 2012. She is a PhD candidate in the field of architectural design at Eskisehir Technical University since 2019. She continues her studies on design behaviors, architectural program, action - body - space relations and architectural education - technology interaction.

Arife KOCA

Arife Koca completes her undergraduate education in Anadolu University, Architecture Department in 2017. She also completed her master education Anadolu University, Architecture Department, Architectural Design in 2019. She continues her doctoral studies at Eskisehir Technical University within the scope of YÖK 100/2000 scholarship. She studies in the field of architectural planning and design, urban design, experiencing and perceiving public space.