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Rafael Ortiz Martínez de Carnero
Architect, researcher and lecturer at the University of Seville, Spain. He holds a Ph.D. in Fine Arts and a Master of Science in Architecture from Pratt Institute. His research focuses on architectural representation, digital visualization, heritage documentation, augmented reality and the integration of immersive technologies into architectural education and design processes.

Shortening the Distance between Representation and Reality: Augmented Reality and the Transformation of Architectural Education

The contemporary transformation of graphical sciences is inseparable from the progressive integration of digital, immersive, and intelligent systems into processes of representation, interpretation, and design. Within this shift, architectural education emerges as a field of experimentation, where the disciplinary legacy of drawing encounters new cognitive and technological conditions. This paper reflects on the evolving role of graphical sciences in architectural education, interpreting augmented reality (AR) as a spatial, cognitive, and interactive environment capable of redefining how students observe, understand, and construct architectural space.
The contribution develops along two complementary lines. First, it frames the current transformation of graphical sciences as a transition from static representation toward immersive, context-aware, and experience-based modes of knowledge production. Second, the paper discusses the educational potential of augmented reality through the lens of architectural pedagogy, focusing on its capacity to strengthen spatial understanding, reduce the interpretative gap between two-dimensional abstraction and three-dimensional experience, and foster more active and situated learning processes.
The reflection is supported by a critical review of recent literature on AR, XR, immersion and spatial cognition, as well as by teaching experiences based on student work developed through augmented reality environments. The paper argues that the future of graphical sciences in education lies in the construction of new pedagogical frameworks able to integrate representation, interaction and critical awareness.

Keywords:
Graphical sciences; architectural education; augmented reality; spatial cognition; immersive learning

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1. INTRODUCTION: GRAPHICAL SCIENCES AND THE TRANSFORMATION OF REPRESENTATION IN ARCHITECTURAL EDUCATION

The contemporary condition is characterized by accelerated technological, cultural, and epistemological transformations that directly affect the ways in which reality is perceived, interpreted, and represented. Within this context, graphical sciences are undergoing a significant redefinition, increasingly functioning as cognitive and operative systems that mediate the relationship between human perception and digital environments. The progressive integration of digital technologies into architectural practice, ranging from parametric modeling and Building Information Modeling (BIM) to immersive environments such as augmented and virtual reality, has contributed to what Carpo (2017) describes as the "second digital turn," in which computational processes are not only instrumental but generative, actively shaping design thinking and knowledge production.
The progressive development of digital technologies has enabled their widespread integration not only within professional design practice, but also across architectural education and research environments. Rather than functioning solely as tools of representation, digital systems have increasingly become operative instruments for exploring and structuring design processes. Early academic initiatives, such as the Paperless Studios at GSAPP (Columbia University, 1994), together with exhibitions like *Architectures Non Standard* at the Pompidou Center (Paris, 2003), already anticipated the transformative potential of computational approaches within architectural research. Through the adoption of techniques including three-dimensional modeling, parametric and algorithmic design, and generative systems, these experiments contributed to redefining both the conceptual and procedural dimensions of the architectural project. Their legacy continues to inform contemporary practice, where digital methodologies play a central role in shaping new modes of design thinking, research, and knowledge production.

Recent reflections within architectural discourse further emphasize this transformation. As highlighted in the exhibition *Stop Drawing: Architecture Beyond Representation* at MAXXI (Rome, 2025), the historical centrality of drawing as the primary medium of architectural thought is increasingly being questioned (Ciorra, 2025, p. 3). The emergence of digital tools, simulation processes, and immersive environments contributes to a redefinition of representation itself, shifting from a static act of depiction toward dynamic systems of interaction and experimentation. In this context, the relationship between architecture and its modes of representation undergoes a profound transformation, affecting not only professional practice but also pedagogical approaches within architectural education.
Traditionally understood as a means of representation and communication, drawing now operates as a dynamic interface between physical and digital realities, enabling new forms of interaction, exploration, and experimentation. As noted by Schön (1983, pp. viii–ix), design processes are inherently reflective, involving iterative cycles of action and interpretation. Today, these processes are increasingly mediated by digital and immersive technologies that expand the possibilities of experiential learning and spatial understanding. In this regard, experiential learning theories, such as those proposed by Kolb (1984, pp. 20–22), emphasize direct engagement, active experimentation, and reflective observation as fundamental components in the construction of knowledge—conditions that are significantly enhanced through immersive environments. Within architectural education, these shifts open the possibility of redefining learning environments as immersive, collaborative, and multi-scalar systems in which students engage directly with spatial data and simulated contexts. As Oxman (2008, pp. 100-102) argues, digital design introduces new forms of thinking and knowledge production, requiring a reconfiguration of pedagogical models capable of addressing the increasing complexity and hybridity of contemporary design processes.

Among the emerging technologies currently reshaping this condition, augmented reality occupies a particularly significant position. Unlike purely virtual environments, AR does not replace the physical world but superimposes digital information onto it, creating a hybrid perceptual condition in which real and virtual dimensions coexist and interact, enabling the visualization of complex spatial relationships and otherwise inaccessible phenomena (Wu et al., 2013, pp. 41-42). For this reason, AR should not be understood merely as an advanced visualization medium, but as a system capable of transforming representation into situated experience, thereby reducing the distance between abstraction and embodied perception. As Sørensen (2006, pp. 25–26) observes, augmented reality enables architectural projects to be studied in situ and at full scale, redefining the relationship between representation and reality.
In professional practice, this transformation is already evident. Das, Brunsgaard and Brøndgaard Madsen (2022) demonstrate, through the analysis of selected Danish architecture firms, that immersive visualization enhances spatial perception and supports creative processes (p. 381). Moreover, these technologies progressively evolve from visualization tools into operative design instruments during early conceptual stages, offering a more effective understanding of spatial configurations than traditional drawings or physical models (Das et al., 2022, p. 385).
Within educational contexts, a growing body of literature indicates that immersive and extended reality environments can enhance spatial cognition, reduce extraneous cognitive load, and support experiential learning (Darwish et al., 2023). At the same time, their pedagogical effectiveness depends not on technological novelty, but on the alignment between instructional design, cognitive processes, and learning frameworks (Wu et al., 2013, pp. 46–47). In this sense, immersive environments are increasingly shifting from representational tools toward active components of both design and learning processes.

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Beyond perception, immersive technologies also enable new forms of communication and collaboration. Within shared virtual environments, architects, students, and stakeholders can engage with spatial proposals in a more intuitive and interactive manner, reducing the interpretative gap typically associated with technical drawings (Das et al., 2022, p. 385). This condition reinforces the pedagogical value of immersive tools, particularly in the early stages of architectural education.
This paper addresses these transformations by exploring the role of immersive technologies in reshaping architectural education, with particular attention to how augmented reality contributes to reducing the distance between representation and reality. Through a research approach developed within an academic context, the study investigates how the integration of AR, BIM, and interactive digital environments influences students' understanding of space, scale, and design processes. From this perspective, immersive technologies are interpreted not simply as tools, but as agents of a broader transformation within graphical sciences, where drawing, modeling, and simulation converge into integrated and adaptive systems of knowledge production.

2. THEORETICAL FRAMEWORK: FROM REPRESENTATION TO IMMERSIVE ENVIRONMENTS

The relationship between representation and reality has always been central to architectural practice and education. Traditionally, drawing has functioned as a mediating device through which ideas are translated into buildable form. This mediation, however, is never neutral; it operates through processes of abstraction, selection, and interpretation, inevitably producing a distance between the represented object and its material realization. Rather than constituting a limitation, this distance has historically defined the space of architectural thinking.
Recent debates suggest that this condition is undergoing a qualitative transformation. The call to "stop drawing" does not imply the disappearance of representation, but rather signals a shift in its role. As digital tools and computational methods redefine design processes, drawing is no longer the primary site of architectural production, but one among multiple forms of mediation. Representation is thus evolving from a descriptive practice toward a procedural and performative one. As Pérez-Gómez (2016, pp. 208–213) argues, architectural representation cannot be understood as a neutral or purely objective medium, but rather as a culturally and linguistically mediated construct that shapes how reality is perceived and interpreted. In this sense, even digital models should not be regarded as direct representations of future buildings, but as interpretative frameworks that influence both design thinking and spatial understanding.
This transformation becomes more evident with the integration of artificial intelligence into architectural workflows. As noted by del Campo and Leach (2022), AI is increasingly embedded within the design process, reshaping both its methodologies and epistemological foundations (p. 7). Representation no longer operates as a fixed output, but within a field of probabilities in which multiple potential configurations coexist. In this context, the architectural project becomes a negotiation between human intention, computational processes, and data-driven outcomes.
Parallel to this development, augmented reality must be understood within a broader trajectory of research exploring the integration of digital information with physical space. Early studies defined AR as a system capable of inserting computer-generated information into the perception of the real world, creating an "augmented workspace" in which digital and physical elements coexist (Wang, 2009, p. 311). Unlike fully virtual environments, AR maintains a continuous relationship with physical space, enabling a more intuitive understanding of spatial configurations and design intentions. This characteristic is particularly relevant in architectural education, where the translation between two-dimensional representations and spatial comprehension has traditionally posed significant challenges. By superimposing digital models onto real environments, augmented reality enables a hybrid perceptual condition in which virtual and real elements coexist, enhancing the perception of reality (Huri et al., 2024, p. 8057).
In this sense, augmented reality should not be considered merely as a visualization tool, but as a design environment. As highlighted by op de Beek (2018), immersive technologies redefine architectural workflows, transforming them into hybrid cognitive systems in which representation, simulation, and interaction converge. Rather than switching between fragmented tools, designers operate within integrated environments that structure information, support decision-making, and mediate between imagination and reality.
Within educational contexts, this transformation is equally significant. A growing body of research demonstrates that augmented reality contributes to improved learning outcomes, increased engagement, and enhanced learning experiences (Garzón, 2021). Traditional design education relies on fragmented systems of representation—plans, sections, and models—that require continuous cognitive translation, often resulting in increased cognitive load (Darwish et al., 2023, pp. 2–3). In contrast, immersive environments provide continuous and situated representations, allowing learners to perceive and evaluate architectural space more directly. As Wu et al. (2013, pp. 41-42) observe, augmented reality enables the visualization of complex spatial relationships and otherwise invisible phenomena, supporting a more immediate and embodied understanding of spatial information.
This transformation, synthetically illustrated in Fig. 1, can be understood as a shift from representation to immersion. Augmented reality operates as an intermediate mediating layer that reduces the interpretative gap between abstraction and experience, enabling situated and interactive forms of knowledge construction (Wu et al., 2013, p. 42). In this context, graphical systems evolve from descriptive tools into cognitive interfaces that extend human perception. As Georgiou and Kyza (2018, pp. 174–175) suggest, immersive environments function as a multi-level continuum of engagement, intensifying attention and perception

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and leading to a deeper integration between user and environment.

At the same time, this shift introduces critical challenges. The increased density of information and interaction may lead to cognitive overload if not carefully structured (Wu et al., 2013, p. 41-42). Moreover, the immediacy of immersive visualization risks obscuring the underlying processes of abstraction that remain fundamental to architectural thinking. The future of graphical sciences, therefore, lies not in replacing representation, but in developing hybrid frameworks that integrate abstraction, interaction, and experience. In this sense, augmented reality expands the field of representation by embedding it within perceptual and spatial contexts.

Within this framework, artificial intelligence further extends the notion of immersive environments, transforming them into adaptive systems capable not only of representing, but also of generating and evaluating design possibilities. Representation thus becomes dynamic, context-aware, and responsive, anticipating a condition in which cognition is partially externalized and computationally supported. From this perspective, the increasing reliance on digital tools also risks reinforcing reductive and instrumental approaches to design, where architecture is conceived primarily as a visual or computational object rather than as an experiential and meaningful environment (Pérez-Gómez, 2016, pp. 208–213).

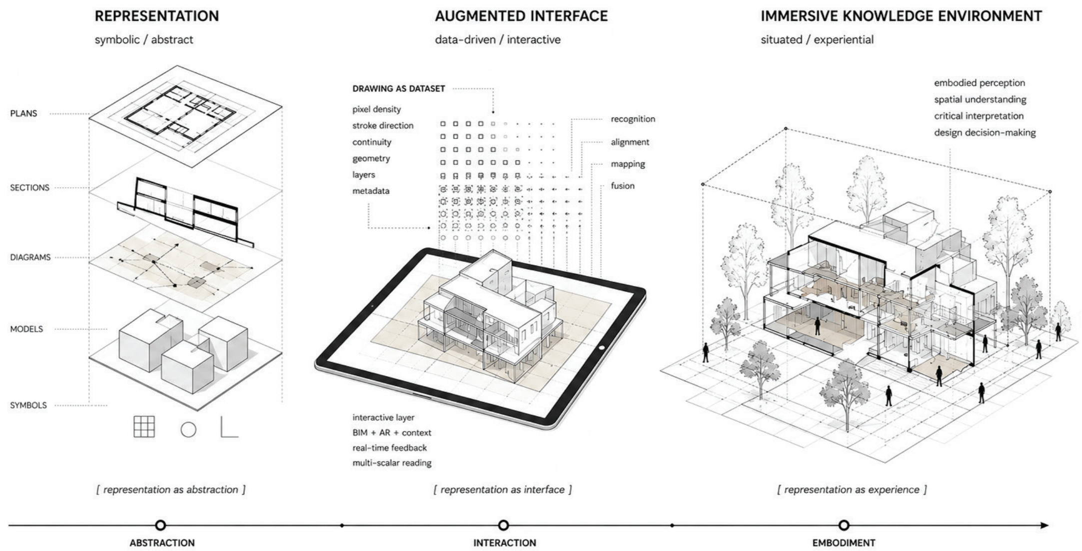

Fig. 1 - From representation to immersion in graphical sciences. The diagram illustrates the transition from traditional symbolic representation toward immersive and interactive environments. Augmented reality operates as an intermediate mediating layer that reduces the cognitive gap between abstraction and spatial experience, enabling situated and embodied forms of understanding. Source: Author (2026).

3. IMMERSION AND ADAPTIVE LEARNING ENVIRONMENTS IN ARCHITECTURAL EDUCATION

3.1. AUGMENTED REALITY AS A COGNITIVE AND SPATIAL INTERFACE

In the transition from representation to immersion outlined in the previous section, immersion emerges as a central condition through which graphical systems operate, redefining how spatial information is perceived, processed, and internalized. However, immersion should not be understood as a purely sensory phenomenon, but rather as a structured cognitive process in which attention, perception, and affective engagement converge to produce a sense of presence within a mediated environment.

In this context, augmented reality introduces a hybrid spatial condition in which physical and digital environments coexist and interact, enabling a situated form of perception that bridges abstraction and experience. As illustrated in Fig. 2, students operate simultaneously within physical and augmented spatial conditions, transforming the act of drawing into an embodied and interactive process. Rather than functioning as a detached representational tool, graphical systems become operative interfaces through which spatial understanding is constructed, negotiated, and evaluated in real time.

3.2. AUGMENTED REALITY AS A PEDAGOGICAL ENVIRONMENT

From a perceptual perspective, augmented reality can be understood through three interrelated dimensions: contextuality, interactivity and spatiality (Krüger et al., 2019, p. 412). Contextuality enables the integration of digital information within real environments, supporting situated forms of learning in which knowledge is embedded directly within spatial context. Interactivity allows users to manipulate and explore architectural content through embodied engagement, combining the affordances of physical and digital environments. Spatiality enhances the perception of three-dimensional relationships, scale, and depth, facilitating a more intuitive understanding of architectural systems. Together, these characteristics redefine how architectural knowledge is constructed, shifting from abstract interpretation toward embodied and experiential understanding (Krüger et al., 2019, pp. 414-416).

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These characteristics are especially valuable in architectural education, where the comprehension of space traditionally depends on the ability to translate two-dimensional representations into three-dimensional understanding. Immersive technologies reduce this cognitive gap by enabling direct engagement with spatial configurations in context. In this sense, augmented reality allows students to engage with architectural works that are geographically distant or otherwise inaccessible, overcoming physical and economic limitations (Shihab et al., 2023). In the present study, where case studies were located in Tokyo, these tools enabled a more precise and situated understanding of spatial proportions, structural systems, and urban relationships. Furthermore, immersive environments support more equitable learning conditions by reducing disparities in access to physical travel and direct spatial experience. Through simulation and contextual visualization, students can engage with architectural space at early stages of learning, fostering a more intuitive and inclusive approach to spatial understanding.

The pedagogical potential of augmented reality can also be understood through multimodal interaction. As noted by White et al. (2007), mixed reality environments incorporate multiple modes of interaction, enabling users to engage with digital content through embodied and physical experiences. In this context, representation evolves from a static medium into an active interface through which spatial, informational, and experiential dimensions are negotiated simultaneously.

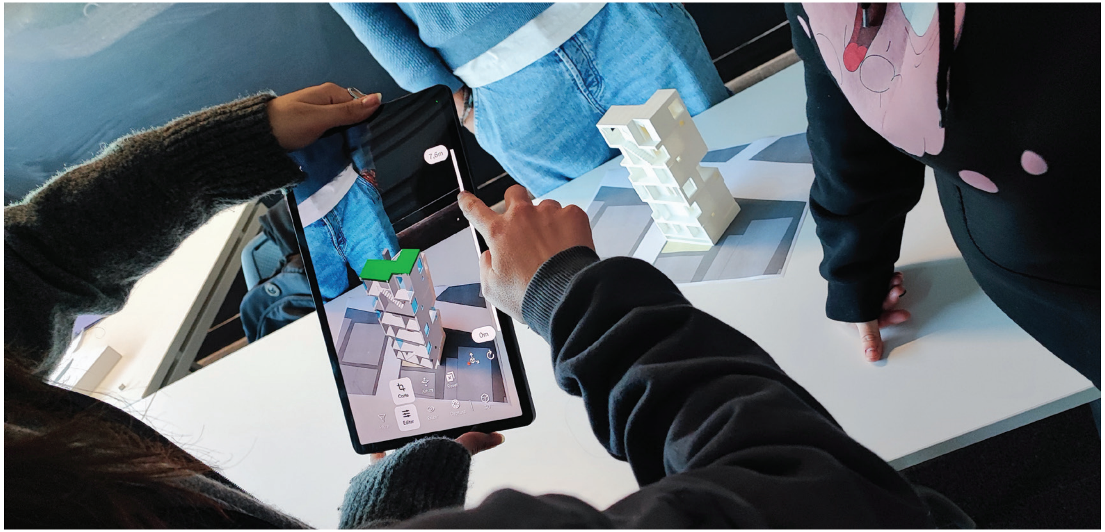

Fig. 2 - Augmented reality interaction in the architectural studio: hybrid visualization between physical model and digital overlay. The image illustrates the transition from abstract representation toward situated spatial cognition, where the student operates simultaneously within real and augmented environments. In this hybrid condition, representation functions as an operative interface mediating between perception, interaction, and spatial understanding. Source: Author (2024).

3.3. HYBRID AND COLLABORATIVE SYSTEMS IN ARCHITECTURAL EDUCATION

The integration of augmented reality with Building Information Modeling (BIM) further expands the possibilities of immersive and collaborative learning environments. This combination enables the visualization of architectural models and associated data directly within physical space, supporting interactive and multi-scalar exploration of design systems. Rather than functioning as isolated tools, BIM and augmented reality operate as interconnected platforms that facilitate decision-making, analysis, and real-time evaluation within shared and dynamic design processes.

Moreover, these technologies promote collaborative learning and interdisciplinary interaction. Augmented environments allow multiple users to engage simultaneously with shared spatial content, fostering communication, problem-solving, and collective understanding. As noted by Fröst and Warren (2000, p. 571), collaborative design processes support the development of shared interpretations and enable participants to formulate, analyze, and evaluate design ideas collectively. The analytical outputs produced by students (Figs. 3-4) demonstrate how immersive environments support the decomposition and reconstruction of architectural systems, reinforcing multi-scalar understanding and interpretative depth. Through the combined use of BIM, augmented reality, and digital modeling, students are able to explore relationships between elements, systems, and spatial configurations in an integrated, dynamic, and collaborative manner.

Despite these advantages, the implementation of immersive technologies within professional practice remains uneven. As Vo (2024) observes, augmented reality (AR), virtual reality (VR), and mixed reality (MR) are still predominantly used for visualization and communication, rather than as fully integrated components of the design process. Their adoption is often limited by economic and organizational constraints, particularly within small and medium-sized practices. Nevertheless, these technologies continue to demonstrate significant potential for enhancing spatial understanding, improving communication, and supporting more informed decision-making processes (Vo, 2024, pp. 34-36).

The theoretical framework developed throughout the previous sections has direct methodological

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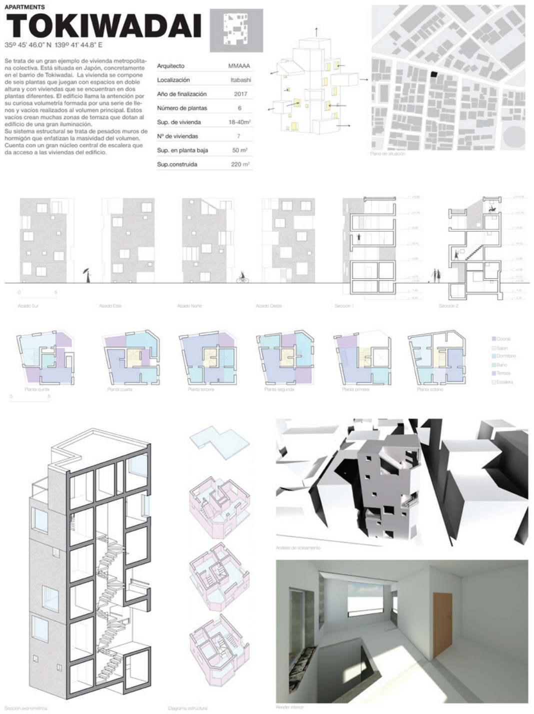

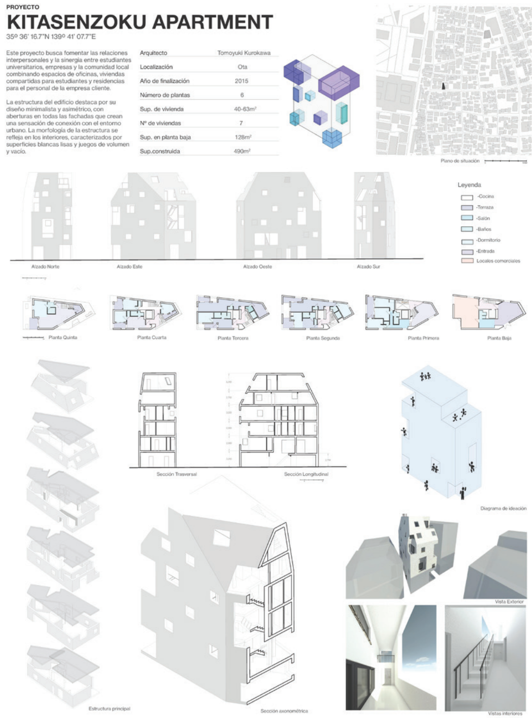

Figs. 3-4 - Analytical student work developed in combination with the use of immersive technologies. Fig. 3 (left): Apartments Tokiwadai, MMAAA (student work). Fig. 4 (right): Kitasenzoku Apartment, Tomoyuki Kurokawa Architects (student work). The images present examples of analytical exercises conducted through the integration of diagrammatic drawing and digital modeling, supporting multi-scalar understanding of architectural systems. The outputs demonstrate how immersive tools enhance the interpretation of structural, spatial, and urban relationships. Source: Author (2025).

implications. If representation is understood as an interactive and situated process rather than as a neutral symbolic system, immersive technologies become operative environments through which architectural knowledge can be explored, interpreted and communicated. From this perspective, the pedagogical experience presented in the following section investigates how augmented reality can support the analysis and interpretation of architectural case studies, enabling students to examine spatial relationships, structural systems and design strategies through hybrid forms of representation and interaction.

4. METHODOLOGY AND CASE STUDY: AUGMENTED REALITY IN ARCHITECTURAL EDUCATION

Building upon these theoretical premises, the proposed methodology examines how immersive technologies can operate as cognitive and representational interfaces within architectural learning environments through a practice-based approach, the integration of augmented reality within different phases of architectural learning, including analysis, research and early design development. In this context, immersive technologies are introduced during the initial stages of architectural education with the aim of evaluating how students engage with processes of visualization, analysis, and design through their incorporation.

The experience was conducted during the 2024/25 academic year within the course Drawing 3: Graphic Analysis, involving 28 students over a period of four months. The results discussed throughout the study are based primarily on the observation and interpretative analysis of the graphical outputs, models, and analytical exercises produced during the activities.

The pedagogical approach is structured around a series of exercises in which the analysis of selected case studies is developed in parallel with the ideation and design of new projects with similar characteristics. Specifically, immersive technologies were applied to the study of contemporary metropolitan housing models addres-

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sing current challenges related to urban density and housing conditions. Through this approach, analytical processes are directly linked to design exploration, enabling students to translate critical observations into operative design strategies. As shown in Figs. 5-6, the coexistence of physical models and augmented visualizations establishes a continuous feedback loop between representation and perception, reinforcing students' ability to evaluate spatial decisions in real time.

4.1. DEVELOPMENT OF THE AUGMENTED REALITY APPLICATION

The augmented reality application was developed using Unity 6, a cross-platform engine widely used for real-time three-dimensional visualization. Its selection was motivated by its capacity to manage complex digital models, support real-time rendering, and integrate interactive elements within a unified environment. Through the use of C# scripting, the application enables the activation, manipulation, and visualization of architectural models detected through mobile devices.

The application was designed for Android devices. Once activated, digital models are projected onto the physical environment through marker-based recognition, allowing for dynamic interaction with architectural proposals. In parallel, commercial applications such as Augin were also employed during class sessions, particularly for the visualization of BIM models and the manipulation of architectural elements through sectioning, scaling, and real-time interaction.

Compared to predefined applications, the use of Unity provides greater flexibility as a research-by-design tool, enabling the adaptation of workflows and visualization strategies to specific pedagogical objectives. This versatility allows for the integration of multiple modeling systems and supports the development of customized learning environments.

4.2. ACTIVATION SYSTEM AND REPRESENTATION STRATEGY

Fig. 5 - Hybrid comparison between physical model and augmented visualization. Augmented reality class session exploring dynamic scales and sectional relationships. The coexistence of analog and digital representations enables a continuous negotiation between abstraction and spatial experience. Source: Author (2024).

Fig. 6 - Simultaneous visualization of a physical model and augmented reality overlay, Tatsumi Apartment House (Hiroyuki Hito); digital model developed by a student. The coexistence of analog and digital representations enables a continuous negotiation between abstraction and spatial experience. Source: Author (2024).

A key component of the methodology is the development of activation targets that establish a correspondence between architectural drawings, physical models, and digital representations. For this purpose, floor plans of the case-study buildings were used as access markers, incorporating their immediate urban context.

One of the main challenges in this process was the need to produce visually complex and distinctive images that could be reliably detected by mobile devices. This requirement contrasts with conventional architectural drawing principles, which typically prioritize clarity and reduction. To address this, a representational system based on a grid of red cross-shaped markers of varying scales was developed, generating a visually dense pattern reminiscent of optical art. As illustrated in Fig. 8, this activation system represents a critical inversion of traditional drawing logic: graphical density, rather than serving clarity, becomes a tool for machine recognition and interaction, reflecting a shift from human-centered representation toward hybrid human–machine systems.

4.3. RESULTS AND PEDAGOGICAL IMPLICATIONS

The implementation of augmented reality within the design studio demonstrates its potential to support new forms of spatial understanding and design exploration. Students are able to interact with architectural models in real time and across multiple scales, enabling a more comprehensive understanding of spatial relationships, structural systems, and urban context.

The analytical outputs produced by students illustrate how immersive environments support the

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decomposition and reconstruction of architectural systems, reinforcing multi-scalar understanding and interpretative depth. Through the combined use of BIM, augmented reality, and physical modeling, students develop an integrated vision of architectural projects, simultaneously engaging with both individual components and overall spatial configurations.
These results suggest that augmented reality not only enhances visualization, but also redefines the role of representation within architectural education, transforming it into an active, interactive, and situated process of knowledge construction.

5. CONCLUSION: GRAPHICAL SCIENCES AND THE FUTURE OF ARCHITECTURAL EDUCATION

The transformations discussed in this paper reveal a fundamental epistemological shift in the role of graphical sciences within architectural education. The future of the discipline can be understood as a transition from representational systems toward integrated, adaptive, and context-aware environments, in which representation evolves from static abstraction into a dynamic interface mediating between data, space, and human cognition. In this context, augmented reality emerges not merely as a visualization technology, but as a mediating interface that transforms representation into an experiential condition, reducing the distance between abstraction and spatial experience. This perspective reinforces the need to understand representation not as a neutral depiction, but as an active and interpretative process embedded in cultural, perceptual, and experiential dimensions (Pérez-Gómez, 2016, pp. 208–210).
The teaching experiences developed in this research demonstrate how augmented reality supports new forms of spatial understanding and design exploration. By enabling students to interact with architectural models within real environments, test design hypotheses at full scale, and evaluate spatial relationships through direct perception, immersive technologies transform representation into an active and performative process. As illustrated in the final outputs (Fig. 9), this integration

Fig. 7 - Augmented reality application workflow and activation system. The interface illustrates the integration of mobile technologies, marker-based recognition, and real-time spatial visualization. Source: Author (2025).

fosters a convergence between analytical rigor and experiential understanding, enhancing both learning outcomes and design capabilities.
At the same time, the integration of augmented reality introduces a shift from linear learning sequences toward continuous feedback systems, in which analysis, representation, and design operate simultaneously. Representation thus evolves into a generative system that actively supports decision-making, interaction, and exploration. However, the effectiveness of these environments depends not on technological novelty, but on their integration within coherent pedagogical frameworks capable of balancing interaction, cognition, and information flow (Wu et al., 2013, p. 41-42; Krüger et al., 2019, pp. 417-418). Moreover, immersive technologies should not replace traditional representational practices, but rather complement them, preserving the analytical and interpretative processes that remain central to architectural thinking.
Beyond the classroom, immersive technologies are increasingly integrated into architectural

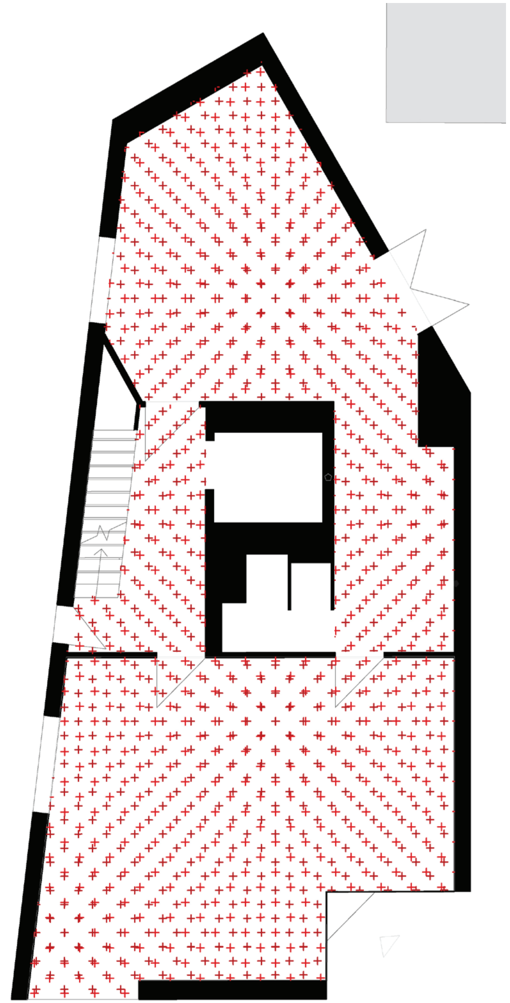

Fig. 8 - Graphical activation pattern for augmented visualization, Kitasenzoku Apartment, Tomoyuki Kurokawa Architects (student work). The image presents the set of activation targets developed for the application, illustrating how drawing conventions are transformed into machine-readable structures, where graphical density operates as a mechanism for recognition and interaction rather than visual clarity. Source: Author (2025).

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workflows that support visualization, communication, and improved understanding in design and construction processes (Chi et al., 2013, pp. 116-118). This convergence suggests that architectural education must anticipate these transformations, preparing students to operate within hybrid environments that combine representation, data, and interaction, and to develop new competencies for navigating complex spatial and informational systems. As suggested by Sørensen (2006, p. 26), augmented reality contributes to reducing the distance between representation and reality not only in visualization, but also in the evaluation of design proposals at different stages of development.

Ultimately, the contribution of this research lies in positioning augmented reality not simply as a technological tool, but as a pedagogical framework capable of integrating spatial perception, interaction, and design reasoning. From this perspective, graphical sciences evolve into an expanded field concerned with the construction of interactive, hybrid, and adaptive knowledge environments, where learning emerges through the continuous interplay between abstraction, experience, and computation. Future developments may further extend these possibilities through the integration of in-situ augmented environments and the visualization of otherwise invisible phenomena, such as environmental, acoustic, or atmospheric conditions, opening new directions for research-through-design and the redefinition of spatial experience within architectural education.

Fig. 9 - Exhibition of developed works combining augmented reality, BIM modeling, 3D printing, and digital architectural representation techniques. The results demonstrate a convergence between analytical rigor and experiential understanding, where representation evolves into a performative, interactive and evaluative medium. Source: Author (2024).

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