An XR-Based Educational Platform for Bridging Architectural Cultural Accessibility and Immersive Learning in Urban Environments

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Architectural education for primary and secondary students in Hong Kong is often limited to static textbook content, with little spatial engagement or connection to students' everyday urban environments. This study introduces an XR-based educational platform designed to bridge this gap, enabling real-time and location-based interaction with architectural sites in Hong Kong. A curriculum-informed framework was developed by analyzing 26 architectural publications to guide content selection, emphasizing cultural narratives, site relevance, and geographic distribution. Based on this framework, 15 architectural sites in Central were selected and categorized into four immersive types: Augmented Reality (AR), Mixed Reality (MR), Augmented Virtuality (AV), and Virtual Reality (VR). Each category supports a distinct learning mode tailored to different site conditions. The platform integrates gesture-based interaction, geospatial positioning, and Passthrough visualization using Oculus Quest headsets to facilitate experiential learning. Initial feedback from educators and students suggests strong potential for improving spatial understanding and learner engagement. This study proposes a scalable approach that embeds architectural education into the urban experience using immersive technologies.

Keywords: *XR, Architectural Education, Immersive Learning, Cultural Dissemination*

INTRODUCTION

Architectural education for primary and secondary students in Hong Kong predominantly relies on traditional methods such as textbooks, classroom instruction, and occasional site visits. While these materials provide foundational knowledge, their two-dimensional nature often fails to effectively bridge the gap between theoretical concepts and real-world spatial understanding. This leads to passive learning experiences, limiting students' spatial cognition and their appreciation of the architectural and cultural significance of their urban environment.

Extended Reality (XR) technologies have emerged as promising tools in architectural education, offering spatial immersion and interactive learning opportunities. However, existing XR applications are primarily developed for professional training, university-level courses, or cultural tourism, and often focus on isolated or interior environments. As a result, their relevance to early architectural education is limited. Recent studies highlight that few XR platforms are aligned with school curricula or designed specifically for younger learners in primary and secondary education (Samala et al., 2024). This creates a gap in accessible, curriculum-informed XR tools that can help students meaningfully engage with architectural concepts in real-world urban contexts. This study addresses this need by proposing an XR platform tailored to Hong Kong's K–12 educational landscape.

This study addresses these limitations by developing an XR-based educational platform designed explicitly for primary and secondary students in Hong Kong. The platform utilizes a curriculum-informed approach to content design, aligning closely with educational objectives and learning outcomes. By incorporating real-time, geolocation-based interactions with architectural sites, the platform provides site-specific immersive learning experiences. Central Hong Kong is selected as the testing area, and the platform's interaction design is structured around four immersive categories, including Augmented Reality (AR), Mixed Reality (MR), Augmented Virtuality (AV), and Virtual Reality (VR), each offering distinct educational engagements suited to different architectural contexts. These categories are based on the reality–virtuality continuum proposed by Milgram and Kishino (1994). AR overlays digital content onto real-world settings, MR enables interaction between physical and virtual elements, AV embeds real-world components within largely virtual scenes, and VR delivers fully digital environments. In this platform, these modes are matched to specific architectural conditions, allowing students to interact with standing buildings through AR and MR, and to explore inaccessible or demolished structures through AV and VR.

CURRENT CHALLENGES IN ARCHITECTURAL EDUCATION

Architectural education for primary and secondary students in Hong Kong faces several critical challenges, particularly the heavy reliance on static teaching methods, insufficient integration into formal curricula, and the absence of systematic frameworks. Traditional educational approaches such as textbooks, lectures, and museum visits primarily utilize two-dimensional materials, which struggle to convey complex three-dimensional spatial concepts effectively. This gap significantly limits students' ability to apply theoretical knowledge to real-world contexts, thereby impacting their spatial comprehension and engagement with architectural learning (Shekhar & Borrego, 2017; Hawkins et al., 2010).

Additionally, architectural education remains insufficiently integrated within core curricula from primary through secondary education levels, resulting in fragmented and often superficial exposure. Research emphasizes the importance of introducing architectural education at an early age to foster deeper appreciation and cultural awareness of the built environment (Sulima, 2020). Interviews conducted locally in Hong Kong highlight that architecture is inconsistently included in liberal studies and other relevant courses, contributing to fragmented and incoherent curricula.

Moreover, current educational initiatives often focus predominantly on historic buildings and preservation efforts, exemplified by programs such as the 'Revitalizing Historic Buildings Through Partnership Scheme' (Ho & Hou, 2019). While these efforts are valuable, they can inadvertently neglect contemporary architecture, thus limiting student exposure and diminishing overall interest in architectural education. Traditional field trips and guided tours, although beneficial, are typically teacher-led, offering limited opportunities for student interaction or exploration. This structured approach can hinder genuine engagement and comprehensive understanding (Lozanovska & Xu, 2013).

To overcome these limitations, there is growing recognition of the potential for immersive technologies such as XR to significantly enhance educational experiences. XR provides interactive and immersive environments, enabling students to engage directly with three-dimensional spatial concepts, thus promoting deeper understanding and appreciation of architectural contexts (Dunleavy et al., 2009; Billinghurst & Dünser, 2012).

XR IN ARCHITECTURAL EDUCATION

XR technologies offer opportunities to enhance architectural education by promoting spatial immersion, interactivity, and context-aware learning. These technologies allow students to engage with architectural concepts directly within real-world contexts, supporting better understanding of spatial and structural principles. Markerless XR systems can facilitate immediate interaction with environments, helping learners grasp complex spatial relationships (Miyake et al., 2017).

Existing XR-based applications illustrate these educational benefits but typically remain limited in scale and scope. For example, applications such as "TimeWarp" in Cologne and "CITY IN TIME" in Hong Kong utilize XR to overlay historical reconstructions onto contemporary urban settings, providing interactive experiences primarily geared toward heritage exploration. These projects effectively leverage XR's capability for contextual storytelling, demonstrating its value in promoting cultural and historical appreciation (Billinghurst & Dünser, 2012). Similarly, XR has proven useful in teaching structural concepts and on-site construction methods, enabling students to better comprehend spatial and technical relationships through interactive visualization (Lima et al., 2023).

However, current XR applications in architecture often exhibit limitations that reduce their suitability as comprehensive educational tools for primary and secondary students. Most existing solutions remain small-scale or confined to interior or isolated sites, limiting their applicability to broader urban contexts. Furthermore, these solutions frequently target professional or specialized heritage audiences, thereby excluding educational curricula and the specific learning requirements of younger students. This narrow professional focus, combined with an overemphasis on historical preservation, typically overlooks modern architecture, further restricting students' exposure to contemporary architectural narratives and diminishing their educational experience.

Therefore, a clear research gap exists regarding the development of XR-based platforms specifically tailored to educational curricula for primary and secondary students. Such platforms should integrate systematic, curriculum-informed architectural content, ensuring pedagogical alignment and comprehensive engagement with both historical and contemporary architecture. Addressing these limitations, this research proposes an XR-based educational platform designed explicitly for urban-scale, curriculum-driven learning. The proposed platform combines AR, MR, AV, and VR technologies into distinct learning paths linked to specific building types. These immersive learning paths offer students dynamic, interactive, and contextually relevant educational experiences, supporting meaningful connections between theoretical knowledge and the three-dimensional architectural spaces they encounter in their everyday urban environment.

This approach aligns closely with experiential learning theory, which emphasizes learning through direct engagement and reflection. According to Kolb (1984), knowledge is developed through the transformation of experience, a model that is particularly applicable to architecture, where spatial and material understanding plays a key role (Yang et al., 2021). XR technologies allow students tox immerse themselves in interactive environments, enabling them to explore architectural forms, construction methods, and urban context through sensory and spatial interaction (Bosman et al., 2024; AlGerafi et al., 2023). This hands-on engagement supports the development of spatial reasoning, sustains attention, and makes learning more memorable and intuitive for younger students (Nistor & Samarasinghe, 2019). By grounding the platform in experiential learning, the educational model benefits from both technological immersion and established pedagogical principles.

METHODOLOGY: XR-BASED EDUCATIONAL PLATFORM

This study presents an XR-based educational platform designed specifically for primary and secondary students, facilitating interactive learning through real-time geolocation-based experiences within authentic urban environments. The main objective is to enhance students' spatial understanding and engagement with Hong Kong architecture by connecting theoretical knowledge from classroom instruction directly to real-world architectural contexts.

The platform integrates four core technological components to enable immersive, real-time architectural exploration. Unity serves as the main development environment, supporting the integration of interactive interfaces, 3D models, and animation logic (Unity Technologies, 2025). ARCore, developed by Google, provides geospatial anchoring and motion tracking, allowing digital content to be accurately overlaid onto real-world building locations (Google, 2025). Meta XR SDK enables hand tracking and gesture-based interaction on compatible devices, facilitating intuitive user engagement in both indoor and outdoor environments (Meta Platforms, 2025). The Google Maps Platform supplies geographic data and coordinate systems used to position architectural content within the urban fabric of Hong Kong. These tools are integrated and optimized for deployment on Oculus Quest headsets, which support mixed reality features such as passthrough visualization and spatial tracking.

Educational content, packaged as geospatially anchored data, is delivered through the Oculus Quest to support outdoor, hands-free learning experiences. Using the headset's passthrough functionality, students view digital overlays directly on physical building façades and urban surroundings. Each site includes interactive visualizations, contextual information, and gesture-responsive interfaces that align with the platform's curriculum-informed design. This immersive approach allows students to connect classroom-based theoretical knowledge with real-world architectural environments in real time.

To ensure that the educational content effectively supports pedagogical objectives, a structured curriculum design process informed by extensive literature analysis was conducted. This approach guided the systematic selection of representative architectural examples and interaction models, aligning directly with clearly defined educational goals. The details of this curriculum design approach are described comprehensively in the following subsections.

Curriculum design

The curriculum design process aimed to select representative architectural examples aligned with the educational objective of understanding Hong Kong's architectural development from 1945 to 2025. This process involved systematically reviewing relevant literature, mapping building mention frequencies and locations, and developing a framework to guide content curation and XR interaction design.

Literature review and content clustering. To establish a foundation for content selection, 26

Figure 1
Selection of 26 Architectural Books on Hong Kong (1990s–2020s)

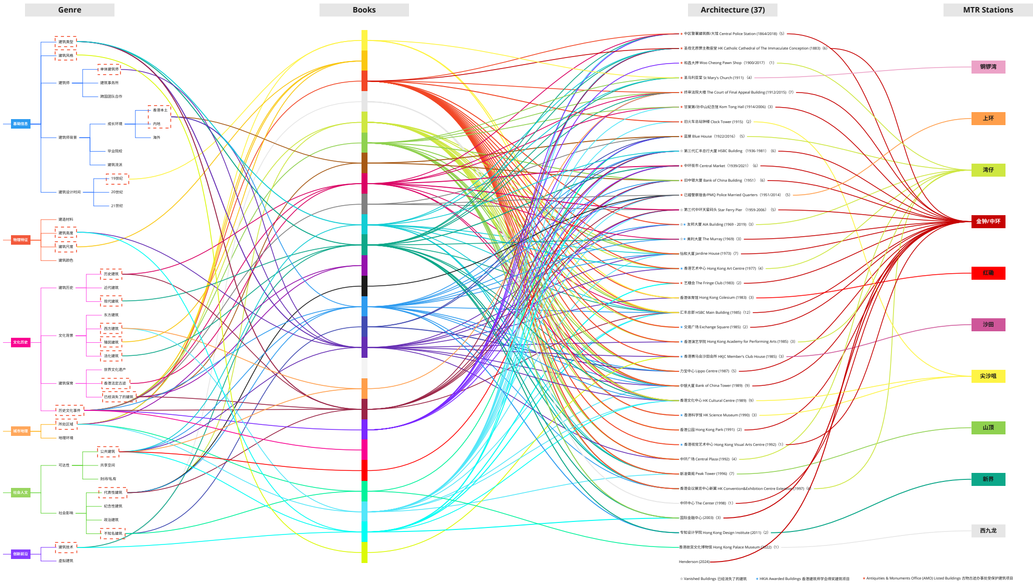

Figure 2
Framework Mapping of Curriculum Design Strategies Based on 26 Architectural Books

architectural books published between the 1990s and 2020s were reviewed. Each book was assigned a color code (Figure 1) and arranged chronologically to identify thematic trends and representation patterns in architectural narratives. This clustering method provided an organized overview of how Hong Kong's architecture has been portrayed over time and informed the following stages of the design process.

Building mention frequency & area mapping. A framework mapping (Figure 2) was constructed to analyze the literature using four components: selection strategies used by authors, book color codes, 37 buildings selected from the literature, and geographic distribution based on MTR locations. These elements were arranged sequentially from left to right to visualize relationships between authors' curatorial principles, the buildings they emphasized, and their physical locations.

Following this, as Figure 3 shows, three separate charts were developed to highlight key data and insights. The first chart identified the most frequently mentioned buildings, with the HSBC Main Building cited 12 times and the Bank of China Tower mentioned 9 times, emphasizing their architectural and cultural prominence. The second chart summarized the five most common principles authors used when selecting buildings, including strategies centered around historical significance, cultural narrative, and geographic representation. Many books structured their content based on regional divisions, selecting representative buildings from each district to offer a comprehensive urban perspective.

The third chart focused on geographic concentration, identifying Central as the region with the highest density of frequently mentioned buildings. Out of 37 significant buildings noted across the literature, 20 were located in Central, highlighting its importance as a representative urban area.

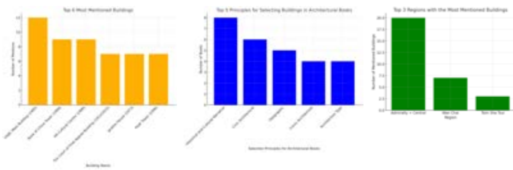

Figure 3
Quantitative Analysis of Architectural Book Content

Geospatial analysis ans site selection. Based on frequency and distribution analysis, Central was selected as the pilot site for the XR platform. The district not only features a high concentration of frequently mentioned buildings but also holds historical, economic, and architectural importance. With its mix of colonial landmarks, postmodern towers, and adaptive reuse projects, Central provides a rich context for immersive educational exploration. Its accessibility and walkability also support practical implementation for school field trips.

Immersive interaction typology. To translate architectural content into meaningful XR experiences, twenty buildings in Central were examined and categorized based on their spatial condition and educational potential. Each building was documented using a standardized information card template (Figure 4), which included its name, image, building status (existing, renovated, demolished), mention frequency, architect, and relevant metadata.

Buildings were then mapped onto a reality-virtuality continuum and grouped into four immersive categories: AR for modern buildings presented with basic contextual annotations; MR for buildings enhanced with interactive overlays or structural insights; AV for renovated structures allowing transitions between past and present forms; and VR for fully reconstructed experiences of demolished sites.

To further refine content selection and interaction design, each building was evaluated across five equally weighted criteria: Historical Significance, Design Aesthetics & Innovation, Accessibility, Social & Cultural Impact, and Narrative & Cultural Fascination. These criteria were defined through a synthesis of architectural literature and pedagogical relevance, with detailed considerations such as the building's iconography, visibility in media, engineering novelty, and connections to civic life. This scoring process enabled the filtering of the initial twenty buildings down to fifteen, ensuring a balanced representation across immersive types and providing a structured basis for designing educational interactions within the XR platform.

Figure 4
Information Cards for 20 Selected Architectural Sites in Central

Main features

The XR-based educational platform comprises six core features: Overview, History, Map, Construction, 3D Model, and Game. These features are distributed across four immersive interaction categories: AR, MR, AV, and VR. Each corresponds to a different mode of interaction and learning objective.

AR: real-time projection and contexual visualization. The AR-based feature introduces basic architectural knowledge and strengthens spatial awareness through real-time projection of visual elements onto the physical environment. The goal is to help students connect spatial form with architectural ideas by using clear, visual augmentation. A central function of the XR technology, Passthrough, enables digital overlays to appear directly on buildings, allowing students to engage with architectural knowledge in context. Most of the core information, including the building's name, function, architect, date of construction, and geographic location, is presented through a digital panel.

As shown in Figure 5, the design of the Bank of China Tower is visualized through layered geometric line projections and simplified structural diagrams. These overlays help students understand complex architectural design ideas, such as the form's gradual transition from large base volumes to a pointed triangular tip. The platform also presents fun facts, like its ranking as the fourth tallest building in Hong

Kong. Through this combination of visual annotation and spatial context, the platform makes abstract concepts more accessible to students.

MR: interactive construction exploration and model interaction. The MR feature provides students with access to deeper layers of architectural knowledge, including how buildings are constructed and how materials are assembled. This is achieved through gesture-based interactions with digital construction components and structural sections. The Interactive Construction Exploration module enables students to examine floor plans, structural systems, and facade assemblies.

In Figure 5, students explore the Bank of China Tower's curtain wall construction by manipulating a digital model of its insulating glass component. They also view sectional details and inspect how steel and glass components are joined together. These interactive experiences allow students to grasp construction principles that would otherwise remain abstract or be difficult to observe in real-world settings.

Figure 5
Interactive Construction Exploration: Viewing Structural Details through XR

Figure 6
Interactive Construction Game: Stacking the Bank of China Tower

The module is further supported by 3D model interaction, allowing students to view and explore entire buildings from multiple perspectives (Figure 6). The 3D Interactive Deciphering Game invites students to assemble simplified architectural volumes, in the shape of four diamond-shaped columns that reflect the tower's form into a coherent structure. With video guidance and hands-on interaction, students build a conceptual model, improving comprehension and encouraging problem-solving. This multimodal approach helps bridge the gap between theoretical and applied architectural learning.

AV: renovation and transformation. This feature leverages AV to allow students to explore the transformation of architectural structures and neighborhoods over time. The educational goal is to provide students with a means to understand architectural evolution by placing virtual building models within the physical world, allowing them to view both exterior and interior details that are often inaccessible in real life.

One of the key technologies enabling this experience is the Selective Passthrough feature of the Oculus Quest. This allows users to frame parts of the physical environment through a passthrough feed, within which digital overlays can appear. For example, as shown in Figure 7, when users align the passthrough window with the Blue House in Wan Chai, they can view a virtual model of the building's interior. This includes floor plans and sectional views, which help students identify specific spatial elements and understand how interior spaces are organized. This is particularly useful in Hong Kong, where many historic buildings are closed to the public or only partially open during limited events.

In addition to viewing the current state of a building, students can use a time slider interface to toggle between different historical versions. For example, they can observe the Blue House before and after its 2016 renovation, which retained existing tenants and involved the community in the conservation process (Figure 8). This award-winning project by Oval Architects provides an ideal case study in adaptive reuse and preservation (Chan, 2017; Chen & Lu, 2023).

Figure 7
Passthrough Window for Interior Exploration

Figure 8
Time-Slider Interface for Renovation and Historical Exploration

The feature also supports broader historical views beyond individual buildings. Students can explore entire urban areas at different points in history. For example, Statue Square in Central can be viewed as it appeared in the 1960s, complete with buildings that no longer exist. These include the Third HSBC Head Office and the Standard Chartered Bank Building. Such comparative experiences help students appreciate urban transformation and the historical layering of the city.

VR: Historical Reconstruction. Building upon the AV feature's timeline capabilities, the VR module expands the experience by immersing students in fully reconstructed environments. While AV allows comparisons between past and present states of existing architecture, VR enables users to explore entire urban areas as they existed in different historical periods. For instance, Statue Square in Central can be viewed as it appeared in the 1960s, complete with buildings that no longer exist, such as the Third HSBC Head Office and the Standard Chartered Bank Building. These comparative experiences help students appreciate urban transformation and the historical layering of the city (Figure 8). Therefore, the educational objective is to allow students to engage with lost architectural heritage, enhancing their understanding of history, memory, and urban change.

Through this experience, students not only observe architectural form but also gain insights into the social and cultural life of different eras. This helps build historical empathy and a deeper appreciation for the value of architectural preservation, making history more tangible and immersive in ways that are not possible through static media or textbooks.

User flow

This section outlines how the XR-based educational platform integrates into the architectural education curriculum for primary and secondary students in Hong Kong. Designed to supplement traditional instruction, the platform enhances learning efficiency by connecting theoretical concepts with real-world spatial understanding through immersive interaction.

As shown in Figure 9, the typical user journey begins in the classroom, where students learn basic architectural concepts, historical context, and design principles through textbooks and teacher-led instruction. They are also introduced to the XR headset and taught how to use its core functions.Next, the teacher leads a field trip to an urban area such as Central, where selected architectural sites are located. Upon arrival, students wear the XR headset to begin exploring the environment. Floating markers appear above buildings, and on-screen instructions guide students in using hand gestures to interact with the system.

Students select buildings of interest and engage with features such as real-time overlays (AR), construction model interaction (MR), renovation timelines and interior views (AV), and historical reconstructions (VR). These tools encourage active

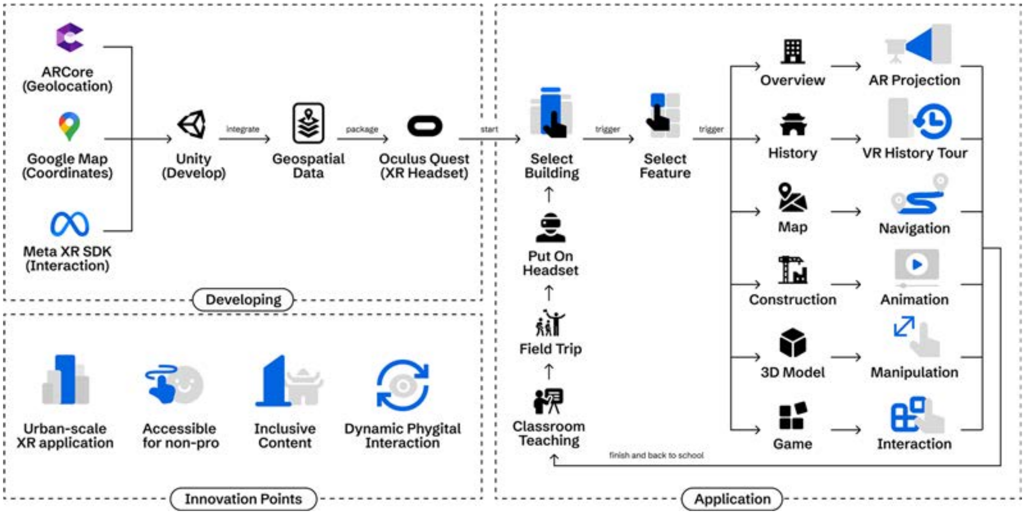

Figure 9
Platform Development and Application Roadmap

learning by combining visual, spatial, and hands-on engagement.

After the field trip, students return to the classroom for a follow-up session that includes discussion, reflection, and assessment. This process reinforces learning and allows teachers to evaluate the platform's impact. The XR experience thus complements the conventional model, providing a more engaging and memorable architectural education.

CONCLUSIONS

This study presents an XR-based educational platform that integrates immersive technologies into architectural education for primary and secondary school students in Hong Kong. Designed as a supplement to traditional textbook-based methods, the platform enhances students' spatial understanding and engagement by connecting theoretical concepts with real-world architectural experiences through geolocation-based interaction.

The project makes four key contributions:

- It expands XR learning beyond isolated environments to city-scale, outdoor educational experiences.
- It translates architectural knowledge into intuitive, visual forms tailored for non-professional audiences, particularly younger learners.
- It bridges both historical and contemporary architecture, helping students understand cultural continuity in the urban fabric.
- It enables hands-on, phygital interaction through real-time overlays, construction animations, and 3D model manipulation.

Informal feedback was collected from 21 individuals, including university design students, doctoral researchers, and a primary school teacher. Although not part of a formal evaluation, these exploratory discussions provided early insights into user expectations and learning engagement. Participants responded positively to the conceptual framework, especially the potential of XR to make architectural knowledge more accessible and engaging across different educational levels.

To advance the platform from concept to implementation, the following development steps are planned:

- Build a working prototype and design a pilot field route in Central, structured by architectural period and style.
- Conduct a within-subjects experiment with 40 primary school students to compare textbook learning with XR-enhanced learning.
- Collaborate with local schools and architecture firms to obtain building data, validate content, and ensure ethical data usage.

While the current focus is on primary and secondary education, the platform's modular design offers scalability. University students studying architecture, planning, or cultural studies could adapt the XR modules for more advanced applications such as structural analysis, comparative urbanism, or heritage research. Ultimately, the platform supports a broader goal: to democratize access to architectural and cultural knowledge by making immersive learning experiences accessible, engaging, and contextually grounded in the city itself.

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