

ARTICLE

Augmenting the Exposure of Extended Reality (XR) Technologies for Architectural Graduate and Undergraduate Students in Hong Kong: On Teaching Initiatives for Virtual-, Augmented- and Mixed Reality (VR/AR/MR)

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ABSTRACT

This Article discusses strategies for the exposure and integration of extended reality (XR) technologies among postgraduate and undergraduate level architecture students in Hong Kong. Explored are collaborative, constructivist, and design thinking frameworks embedded into the course curriculum, teaching workshops, and design activities for the promotion of hybrid (physical and digital) learning.

Programmes such as those at The Chinese University of Hong Kong (CUHK) do not consider XR as part of the core curriculum, resulting in students successfully completing a degree without exposure to the technology, platforms, and methods, leaving them unprepared for an increasingly digital future in professional practice. This study examines strategies for hybrid teaching and learning initiatives, student exposure to ongoing research and development of emerging technologies, and preparation for a future industry that mixes digital, physical, and virtual practice in architecture. It showcases different approaches for technology-facilitated teaching and learning using mixed reality design and build workshops in public university spaces, the integration of XR methods and hardware within studio and elective course curriculum, and crossover studio workshops available for faculty and students.

Results of an online questionnaire for students ($n = 34$) reflected a high need for learning AR in architectural education. Participants agreed that augmented reality (AR) technology can enhance design thinking process and self-learning, and lead to a more effective architectural practice. Major learning obstacles include the lack of technical support and relevant knowledge, accessibility to specific tools and pre-occupied academic schedules by other schoolwork.

By keeping instructors and students engaged with novel XR technology, programmes and graduates will remain competitive in academic and professional pursuits. They develop novel hybrid workflows and methods for design-driven research in a future practice where digital, physical, online, and offline learning become increasingly fluid.

Keywords: Augmented/virtual reality, learning-oriented technologies, curriculum and syllabus design, tools and platforms

INTRODUCTION

Extended reality

We are entering a new digital era, shifting from the internet age towards an augmented age (King, 2016), or as recently labelled, the metaverse (Reaume, 2022). Here, users will enter virtual or augmented reality (AR/VR) environments. This is where they can connect with friends, work, visit remote locations and more, all in immersive spaces mediated by the rise of technological extended reality (XR) devices. These devices will replace conventional computers and smartphones through overlaying information over our field of vision in form of glasses or lenses where the digital will be in full fusion with the physical world, or completely replacing it (Figure 1).



Figure 1. Holograms as part of our daily lives: [Hyper-Reality](#) by Keiichi Matsuda, 2016.

[Source: Matsuda, K (2016). [Hyper-Reality](#). Accessed 2022-02-10.]

Extended reality (XR), as the umbrella term for virtual-, augmented- and mixed reality (VR/AR/MR), is becoming progressively ubiquitous throughout multiple fields, as seen on social media platforms, gaming, medicine, engineering, the arts, and so on. VR as being fully immersive, separates the user from the real world and their traditional tools. VR and AR can be positioned at opposite ends of the spectrum, with VR placing the user in a completely computer-generated virtual world, and AR being a system that blends computer-generated 3D models together with the physical context, preserving the user's awareness and ability to interact with the real world (Jahn et al., 2018). Mixed reality is based on AR, but instead of just displaying digital content, it is merging the physical and digital together by contextualising information. This fusion between the digital and real-world environment will transform our workspaces and perception of reality through immersive solutions (Papagiannis, 2017). XR has the potential to increase productivity as the advancing technologies of the tools allow users to sense their surroundings, track the user's position, detect real-world objects, and enable us to interact simultaneously with the virtual and physical world.

The study presents opportunities for increased integration of XR technology in the graduate and undergraduate curriculum at CUHK. A higher exposure of XR in the Asian educational community will benefit the gradual global awareness and international recognition of our students to become competitive, pioneering, and forward thinking in the field of emerging technologies, allowing them to participate and shape the early stages of the augmented age and metaverse.

Studio and lab-based learning environments

Even though there is great amount of research being published about the integration of XR technologies in the Asian educational community, there is a gap between the exposure of these technologies between postgraduate researchers and those within the graduate and undergraduate school.

Studio-based teaching and learning is unique in developing essential qualities among students, summarised as the ‘making culture’. These qualities include craftsmanship, design thinking, problem solving, and adoption of an action-based iterative approach (Fingrut, 2020) often associated with hands-on and experience-based learning. Pedagogical approaches in studio learning are designed to mimic similar environments found in professional practice and are considered “ubiquitous in the discipline and associated somewhat uniquely with the profession” (Shulman, 2005). Sometimes associated the development of creative works, the term ‘studio’ can refer to those environments classified as flexible spaces for groups of students to conduct their academic research and development activities typically associated with hands-on learning methods such as in architecture, the visual arts, industrial design, and may be considered synonymous with the ‘laboratory’. It is important to note that these spaces are collaborative by nature, promote peer-to-peer learning, and benefit from participants gaining peripheral awareness of other students’ work. This study considers the “signature pedagogy” (Shulman, 2005) of conditions found within the studio environment that highlight: a) knowledge development through peer learning; b) skills development through new workflows; and c) professional preparation.

Pedagogical approaches can be further broken down into activities associated with teaching and learning exercises (Table 1). These activities are used as methods for students to gain exposure and confidence in tasks they may encounter in professional practice, as well as aligning with evaluation criterion for professional accreditation. Although all significant, this study emphasises tasks relating to experimentation, practice, articulation, and synthesising—each of which is associated with the physicality and spatial attributes contained within the studio environment, laboratory or in the field (Figures 2-3). These are examples of constructivist activities (Piaget, 1971), where one gains active knowledge gain by learning from sensory experiences, rather than through passive “sitting and listening” (Tularam & Machissella, 2018).

Table 1

Five principal media forms with the learning experiences they support, and the methods used to deliver them. (Laurillard, 2002, p. 90)

<i>Learning Experience</i>	<i>Methods / Technologies</i>	<i>Media Forms</i>
Attending, Apprehending	Print, TV, video, DVD	Narrative
Investigating, Exploring	Library, CD, DVD, Web Resources	Interactive
Discussing, Debating	Seminar, online conference	Communicative
Experimenting, Practicing	Laboratory, field trip, simulation	Adaptive
Articulating, expressing	Essay, product, animation, model	Productive



Figure 2. Architecture Design Studio. Hong Kong. 2021



Figure 3. Fine Arts drawing within studio. Hong Kong. 2021

Hands-on learning is a method of instruction whereby students fundamentally gain knowledge from experience (Ekwueme et al., 2015). This method of instruction is significantly different from lecture-based learning activities, as it implicitly adopts many of the phases associated with design thinking through observation and reflection. It has been shown to develop student ability in problem definition; problem solving; modes of cognition; nonverbal thought; and communication (Gwangwava, 2021). Gwangwava continues by describing “workspaces that promote free expression of oneself, critiques, sketching, modelling, prototyping, and iteration”(2021, p. 16). This is significant as it describes conditions, environments, and activities attributed to studio-based higher learning programmes.

Most research around digital and virtual learning is grounded in technology that enhances communication. What makes this XR research unique is the focus on studio-based learning environments, where haptic knowledge gain, physical and material explorations are intrinsically tied to the traditional academic experience. It allows participants to transcend typical limitations found in technology usage as fundamentally a communication tool, and into the realm of physical and material *making culture* found through the traditional development of haptic knowledge (Mizban & Roberts, 2006).

While it is generally accepted that virtual learning can make education more widely accessible and can be a useful substitute when face-to-face classes are no longer feasible (such as during the COVID-19 pandemic), not all higher education institutions have realised the fullest potential of XR avenues for learning in the curriculum. Part of the reason is the rigidity of traditional pedagogical approaches that are ill-suited in a digital age. In 1993, Diana Laurillard published a framework of five principal forms of media analysis along with matching media forms (Laurillard, 1993). With reference to Laurillard’s framework (Table 1), some media forms (e.g., narrative, interactive, and communicative) can be well served with existing tools (e.g., instant messaging, video conferencing, web-based virtual learning environments), yet others (e.g., adaptive, and productive) are difficult to achieve in an online setting alone.

Unequal access to technology such as 3D scanners, VR and AR equipment among students and varying technical competency among teachers also poses a challenge to the wider implementation of XR learning. Additionally, emerging XR tools require expensive, high-powered computers, and graphic processors to sufficiently support minimum device specifications. In architecture departments, typical studio units consist of 10-15 students per instructor, with a multitude of units within any undergraduate or graduate programme. The numbers can quickly add up to a costly investment in a technology that is rapidly advancing; without a firm understanding of equipment shelf life, this can seem risky against fixed budgets.

This disparity is also exacerbated by an understandable need to retain a traditional pedagogy that includes the rudiments of studio-based activities such as construction of handmade models, and creation of physical drawings at the expense of digital and virtual fluency. Finding the correct balance and approach toward achieving ambidextrous teaching profiles that find a “best blended approach” toward physical, online, virtual, and augmented, can often require significant foundational changes to the curriculum that require instructor commitments, resources, and time to implement.

METHODOLOGY

To implement and integrate XR technologies with architectural education, various workshops were conducted by the authors. These include the “Integrating Augmented-Reality with Design Thinking (AR-DT)” initiative, XR design-and-build workshops, Argan, CAADRIA XR workshops, and “XR Teaching Integration in Studio”. The outcomes on architectural education by each implementation are summarised in Table 2.

Table 2

Outcomes of application of XR technologies on architectural education from author’s experiences

<i>XR technologies / methods</i>	<i>Outcomes on Architectural Education</i>
Integrating Augmented-Reality with Design Thinking (AR-DT)	
3D point-cloud scanning	Documentation of site conditions into scaled 3D models in a short period of time, compared to conventional site measurements and visits
On-site virtual projection (Fologram)	Interactive testing of design options in response to existing site environment; Streamlined and enhanced design processes by its intuitive and instantaneous interface
Video recording of virtual projection (Fologram on iPad)	User-friendly screen video recording of the virtual projection on iPad for future dissemination and self-access by other students
XR Design-and-Build Workshops and ARgan	
AR holographic instructions	Alternative to conventional 2D construction documentations for which training for reading and 2D-3D translations are required
MR integrated fabrication and collaborative assembly	Affordable alternative in building contexts with limited means and available resources for costly digital fabrication tools (e.g. CNC machines and robotic arms); Creative collaborative production workflows for building a geometrically complex digitally drafted design to physically built shape.
CAADRIA XR Workshop	
Augmented feedback loop between Rhino and HMD (scanning markers as tracked points)	Digitally track indeterminacies between the as-built and digital design model; Refinement of digital simulation tools in real-time
XR Teaching Integration In Studio	
Online VR immersive platforms (e.g. Mindesk, Gravity sketch)	Alternative method for presentation of design materials from within an immersive 3D environment

Integrating augmented reality with design thinking

Funded by CUHK¹, the authors initiated a teaching and learning (T&L) project titled “Integrating Augmented-Reality with Design Thinking (AR-DT)” in self-directed teaching and learning by postgraduate architecture students. In this initiative, XR has been introduced to various courses and modules on a voluntary basis including architectural design studios, elective courses, and research projects. A four-step sequential design of T&L activities has been adopted for best peer learning outcomes—an introductory workshop, tutorials for champion students, project integration, and documentation.

Firstly, a school-wide introductory workshop was organised to inform students of the latest technology, tools available and upcoming activities (Figure 4). Participants at various academic years and design studios were recruited to encourage inter-class interaction. In the first half of the workshop, the workshop instructors presented various XR research projects to the attendees. The purpose of this was to familiarise the participants with the potential applications of XR in the realm of architecture and help them gain a fundamental understanding of its possibilities. In the second half of workshop, students were provided with the essential equipment and configuration for hands-on experiences. At the end of workshop, students were invited to volunteer as champion students to take the lead in disseminating knowledge with peers in their own projects.



Figure 4. Schoolwide Introductory workshop organised by the authors.

Subsequently, small-group tutorials were conducted for individual courses for in-depth knowledge exchange. Both face-to-face and virtual sessions were offered according to the teaching arrangement of tutors respectively. During the tutorials, selected champion students were offered essential XR knowledge, including conceptual, attitudinal, and procedural content to solve problems in real world and achieve personal goals (Zollman, 2012). In view of the pedagogical differences between studios, students were mainly taught with the basics to manipulate a handful of tools, configure essential hardware, and define their own XR tasks so as to maintain a high level of freedom in self-directed learning. A range of operations were demonstrated, including 3D point-cloud scanning activity using mobile devices with a LiDAR sensor (i.e., Apple iPad 2020), real-time virtual projections using Fologram (Jahn et al., 2020) on tablets, and Rhinoceros3D (Robert McNeel & Associates, 2021) on laptop via a virtual network connection, and immersive AR projections using wearable headsets (i.e., Microsoft HoloLens 2 and Varjo XR-3) connected to desktop workstations.

In the next step, course tutors were invited to collaborate on integrating XR applications with their existing assignments to students. It is argued that effective learning occurs by providing learners with opportunities to design their own learning via practical experiences in the learning process (Jurković et al., 2013). The

assignment integration was stimulated in a way to respect individual tutors, avoid adding extra teaching burdens and minimising pedagogical interference. This was done with a pre-designed curriculum while demonstrating the high feasibility of applying XR technology in a spectrum of T&L activities, as willingness to adopt new technology among teachers are influenced by their individual attitudes (Sugar et al., 2004). Performance of XR application in assignments are not included in the assessment criteria, so as to motivate learners to engage in free experimentation within their own projects. To illustrate, the integration with an elective course—“Topical Studies in Building Technology – Function or Ornament: Rethinking Breeze Blocks”—is discussed here.

In this course, five groups of students were asked to complete three assignments: precedent study on breeze blocks, fabrication of prototype, and pavilion design. To explore, students were invited to define, on their own, the tools and outcomes of XR application in the pavilion design assignment. Two groups adopted 3D point-cloud scanning to capture the essence of the site and document it into a digital model (Figure 5).



Figure 5. Screenshot of 3D point clouding digital model in Rhinoceros.

During the pandemic, 3D scanning enabled students to document site conditions in a short period of time, compared to conventional site measurements, and reduced the risk of interpersonal infection. With both materiality and dimensions documented in the digital model, a more efficient and effective design iteration could be achieved.

In addition, three groups experimented with the composition, scale, and site responses using virtual projections on Fologram. Design options with different façade patterns were tested interactively while being instantaneously aligned to the existing site environment (Figure 6)



Figure 6. Screenshot of on-site virtual projection of facade patterns through Fologram on Apple iPad

The spatial arrangement of a pavilion in an alley in response to existing buildings and moving pedestrians was examined (Figure 7).

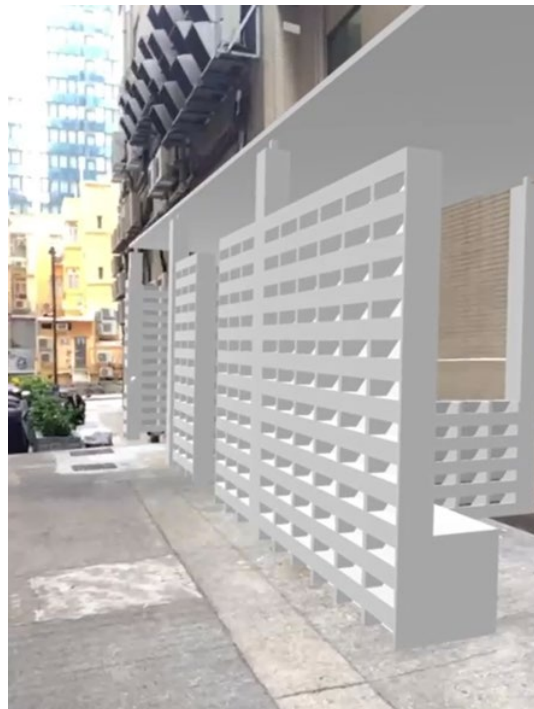


Figure 7. Screenshot of on-site virtual projection of the pavilion in alley through Fologram on Apple iPad

All groups demonstrated how the interactivity of the XR application has streamlined and enhanced design processes by its intuitive and instantaneous interface.

Throughout the experimentation, students were required to do video recordings of the process, including all trial-and-error moments. All short clips were then uploaded to a central archive (i.e. [YouTube channel](#)) to facilitate access by other students. All together, this established a sustainable flow of self-directed learning activities in XR applications.

XR design-and-build workshops

This study highlights two XR design-and-build workshops at CUHK within the past few years. Both workshops challenged students to engage in mixed reality (MR) fabrication techniques for the fabrication and assembly of a set of complex bamboo structures.

Students were exposed to 3D AR holographic instructions which allowed them to perform complex operations by perceiving geometrical relations intuitively through overlaying digital design information onto their field of view. 3D AR holographic instructions offer a noteworthy alternative to conventional 2D construction documentations, which require expertise and training in the reading and translation of 2D instruction to 3D problems.

The workshops were set out such that students could explore the opportunities of MR integration in the fabrication and assembly processes of non-standard architecture. In such cases, MR presents an affordable alternative in building contexts with limited means and available resources for costly digital fabrication tools such as computer-numerically-controlled (CNC) machines or robotic arms. Holographic-aided setups were designed and streamed on multiple devices, including a series of Microsoft HoloLens and several handheld smartphones, all being simultaneously connected to a single digital model to interactively guide the assembly and fabrication process through holographic building instructions (Goepel & Crolla, 2020). This set of digital information was holographically overlayed onto the student's field of vision to guide them during the crucial steps of the production sequence.

These workshops showcase how the integration of AR in bamboo construction and design can augment existing craftsmanship and the enlargement of its associated practically feasible design solution space. They allow students to critically reflect on traditional 2D annotation techniques by experiencing the benefits of XR in construction by being engaged in a hands-on fashion.

a) ARgan

The ARgan workshop (Goepel & Crolla, 2020) centred on creative collaborative production workflows through XR tools, in which students could engage in all steps of the fabrication and assembly process to bring about a geometrically complex digitally drafted design to its final physically built shape. The first exercise was to project the digital assembled parts in the workshop spaces through AR to check their scale in the physical space. Students could adjust the scale through the sliders in the user interface on their smartphones to adjust the parts so that they would fit through physical obstacles such as doorframes (Figure 8).



Figure 8. Scaling of project based on space availability using AR

This exercise can be extended to any of the student's future designs for an immersive AR experience. The students were also learning how to combine computational design tools with AR, allowing them to sequentially

utilise MR for the pre-fabrication of bamboo splits and assembly through its simultaneous joint creation (Figure 9).

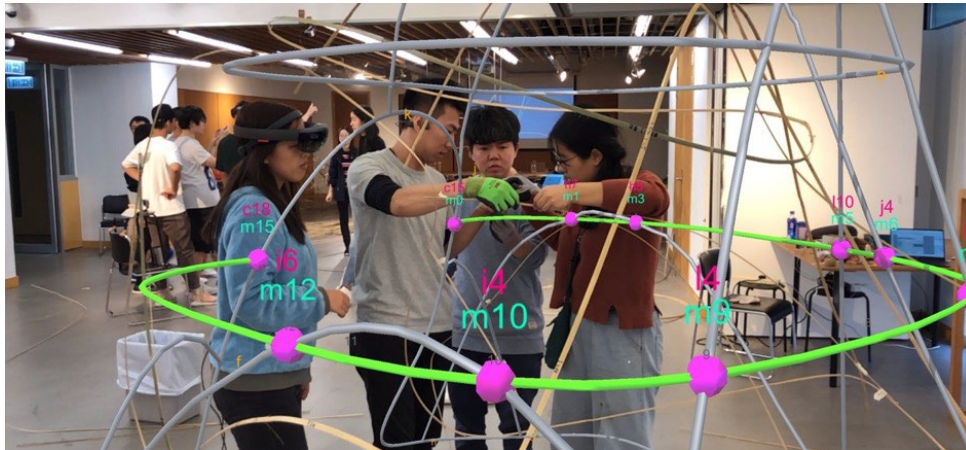


Figure 9. Interconnecting bamboo following holographic instructions from HoloLens

The installation was divided into four main components which were constructed collaboratively throughout the workshop. Once all components were assembled, they were moved into the atrium spaces for their final assembly and densification through 3D AR holographic instructions (Figures 10 and 11).



Figure 10. Assembly of components into the final structure.

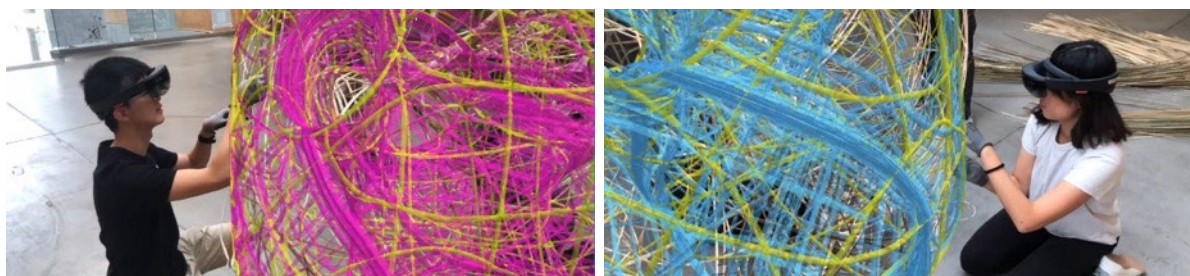


Figure 11. Densification of the final assembly following holographically overlaid flow patterns.

techniques by actively integrating an augmented feedback loop within the fabrication cycle to grasp the advantages of how these can aid in the refinement of digital simulation tools in real time (Figure 14).

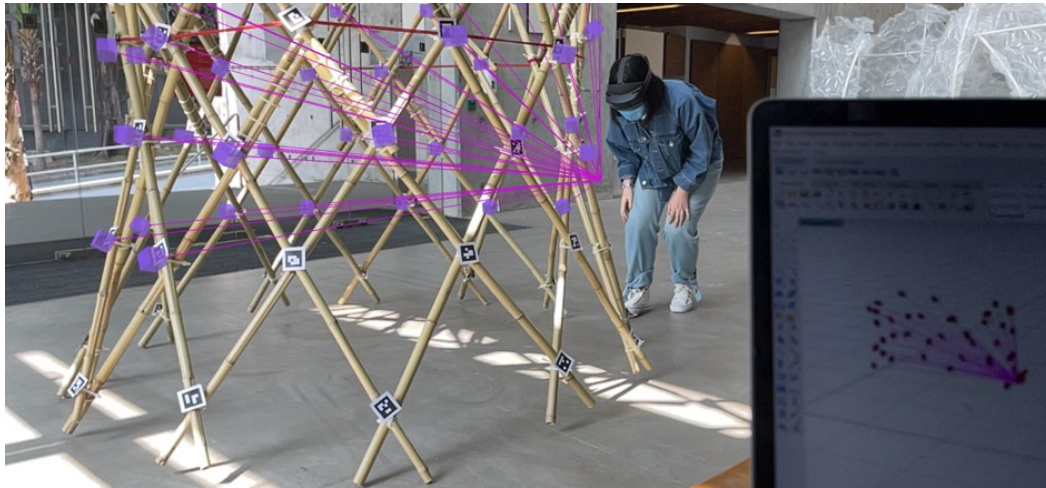


Figure 14. Scanning Aruco markers on the installation. Live stream between Rhino and the HMD to bring the tracked points back into a 3D environment.

The location of both workshops was accessible to all CUHK students as the sessions were held in open exhibition spaces and the main atrium, which is the most circulated space of CUHK's School of Architecture (Figure 15). This allowed curious students glimpses of the integration of XR tools in practice even without actively participating in the workshop. Numerous students were testing head-mounted mixed reality devices for the first time as these were on public display, rather than operated in secluded spaces. The open location was successful in engaging non-participating students passing through as there was no threshold between the workshop session, the XR tools and the atrium space, commonly utilised as a place for social gatherings and lunch breaks. Bringing XR tools to the fingertips of students in their common spaces allows them to actively experience, engage, and participate in new emerging technologies, particularly in construction-related fields. Here, developments in XR hardware and software technology will play an increasingly important role in today's architectural context, which aims to enlarge the impact from digital technology through its integration into praxis.



Figure 15. CAADIRA workshop installation at the School of Architecture atrium at CUHK.

XR teaching integration in studio

Next to workshops, XR is also integrated in studio teaching. One postgraduate architectural design studio at CUHK was developed to place emphasis on XR as one of its key technical teaching priorities. XR was integrated as part of a series of planned assignments and projects designed for students to adopt a hybrid and ambidextrous approach to their architectural learning experience (Figures 16 and 17). Assignments were categorised by the type of technology employed, and production as being analog or digital (Table 3). Broadly, the pedagogical approach considered aspects of exploring and observing physical materials and phenomenon, translation into 3D environments via digitisation processes, manipulation using 3D modelling tools, computational workflows and VR immersive platforms, and synthesis into outputs using a mixture of media, CNC-driven fabrication tools, and traditional techniques.



Figure 16. Student with VR headset at home.



Figure 17. Student presenting his design intent through VR in the atrium space

For example, Assignment A may be conducted as a hand-drawing using graphite pencils on paper, while a follow-up Assignment B would involve the digitisation process of A, VR-based manipulation of scanned geometry, producing output such as a 3D shared representation, and a physical model of surfaces generated through the design process. Online platforms that support real-time sharing of geometry such as Mindesk (Mindesk, 2021) and Gravity sketch (Gravity sketch, 2021) were used to present and discuss materials from within an immersive 3D environment.

Each assignment was supported by sufficient associated technology, such as VR headsets or 3D scanning devices that could be exclusively borrowed for the duration of the assignment or term by participants. These were further supported by introductory workshops that gave students primers and exposure to basic use of the associated equipment, supporting software, as well as digital design methods to instill sufficient confidence in the students' adoption and exploration of the tools.

During presentations, students were advised to bifurcate their explanation of assignment production experiences into two key discussion areas: 1) qualitative aspects of the work they produced including narratives, design decisions, and compositional strategies; 2) quantitative and technical aspects of their production activities associated with their own methods. These quantitative descriptions include entity relationship diagrams that illustrate their own unique workflows developed, mechanical or technical explanations of the tools they adopted, and general insights into the successes and failures encountered when using such technology. Presentations would act as technical sharing sessions that provided students opportunities to learn from a multitude of original workflows, provide alternative methods for more effective design and technology uses, and opportunities to refine based on both qualitative and quantitative interests as part of future assignments and projects.

Table 3

Six examples of student assignments driven by digital and analog tools and methods, experienced with physical and VR integration. (Hong Kong, 2022)

<i>Asgmt.</i>	<i>Description</i>	<i>Methods</i>	<i>Technology</i>	<i>Experience</i>
A	Life Drawing	Hand Drawing	Pencil/Graphite	Analog
B	Digital Drawing (A)	Vector Drawing	Scanners/3D Modelers	VR
C	Surface Model (B)	Material Cutting	CNC Tools	VR/Analog
D	Volume Model (C)	Casting	CNC / Hand Tools	VR/Analog
E	Assemblies (D)	Connecting Casts	CNC / Hand Tools	VR/Analog
F	Space (E)	Model / Drawing	CNC / Digital Renders	VR/Analog

RESULTS

Cross Studio XR workshops

To better understand learners' needs and the current learning environment, an online questionnaire was distributed to solicit feedback on initial perception towards AR and design thinking. Participants were confirmed to have little to no practical experience using AR, VR, or XR as part of their historical learning experiences ahead of the workshops.

Participants ($n = 34$) reflected a low-to-average understanding towards the concept of AR (Figure 18), a low familiarity with state-of-the-art AR technology (Figure 19) and an insufficient experience in the application of AR (Figure 20). Participants also reflected a high need in learning about AR in architectural design (Figure 21). With the fair understanding of design thinking (Figure 22), most participants agreed that AR technology can enhance design thinking and lead to a more effective architectural practice (Figures 23 and 24). Furthermore, it is agreed that technology can enhance self-directed learning (Figure 25), and AR can bring significant changes in architectural representation (Figure 26). The conducted workshops itself vary in content, but all had the same intention to teach students XR without prior architectural XR knowledge. This study does not compare the workshops' content, but rather the experience and exposure of XR tools and techniques to the students.

How much do you know about the concept of Augmented Reality (AR)?

34 則回應

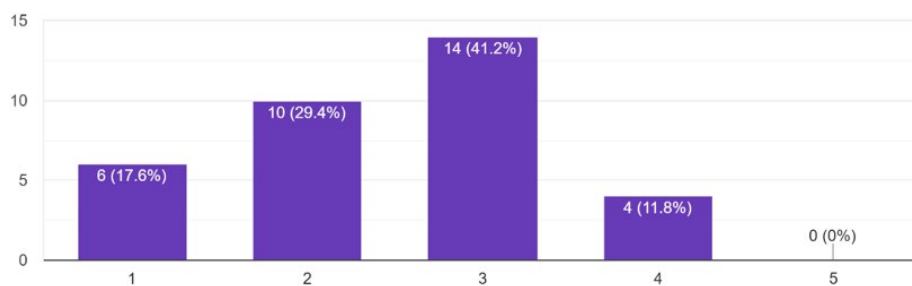


Figure 18. A low-to-average understanding towards the concept of AR
(1 = Least, 5 = Most)

How familiar are you with state-of-the-art AR technology?

34 則回應

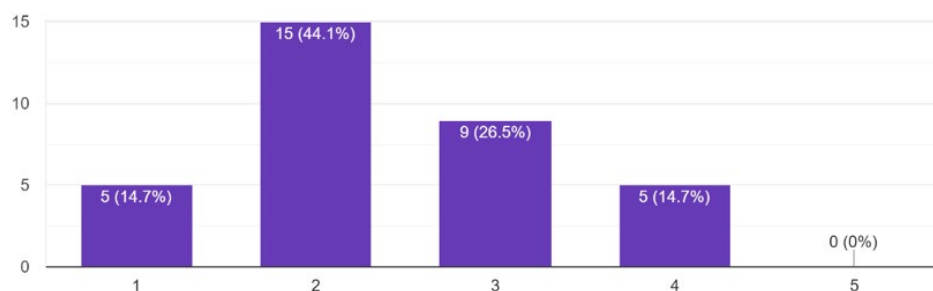


Figure 19. A low-familiarity with state-of-the-art AR technology
(1 = Least, 5 = Most)

How experienced are you in the application of AR?

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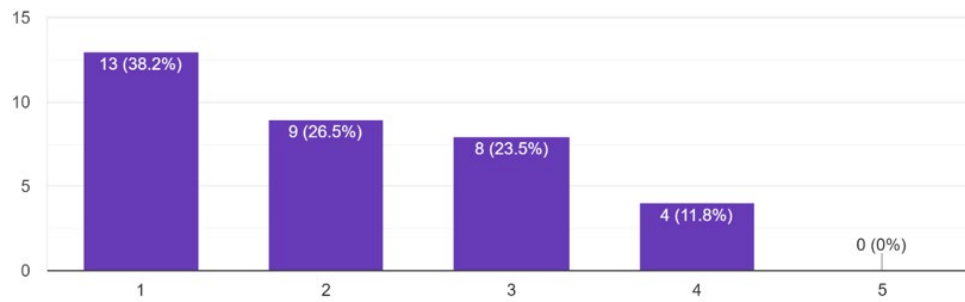


Figure 20. An insufficient experience in application of AR (1 = Least, 5 = Most)

Do you think there is a need to learn about AR in architectural design?

34 則回應

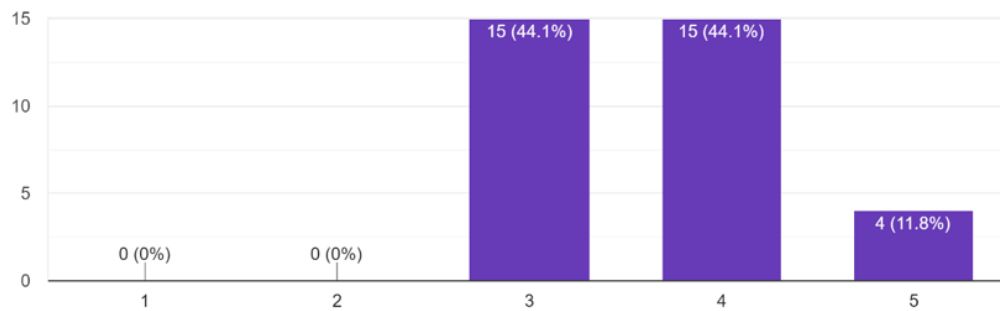


Figure 21. A high need in learning about AR in architectural design (1 = Least, 5 = Most)

Are you familiar with the concept of design thinking?

34 則回應

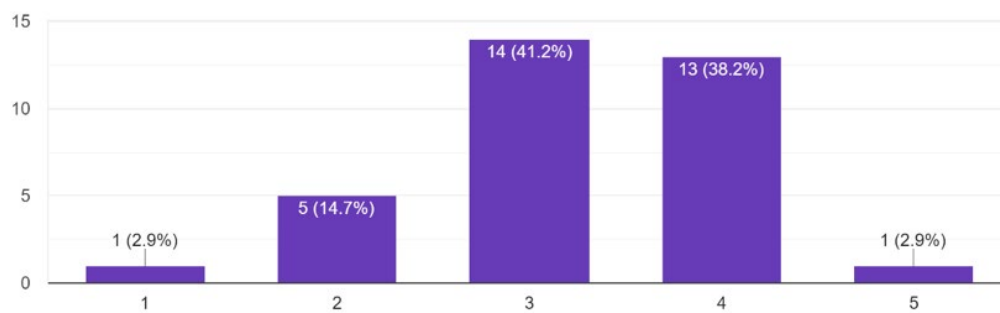


Figure 22. A fair understanding of design thinking (1 = Least, 5 = Most)

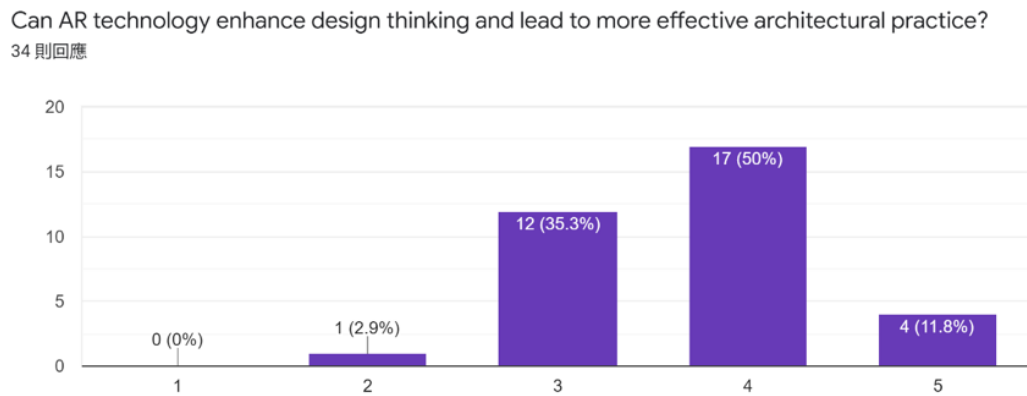


Figure 23. Most participants agreed that AR technology can enhance design thinking and lead to a more effective architectural practice (1 = Least, 5 = Most)

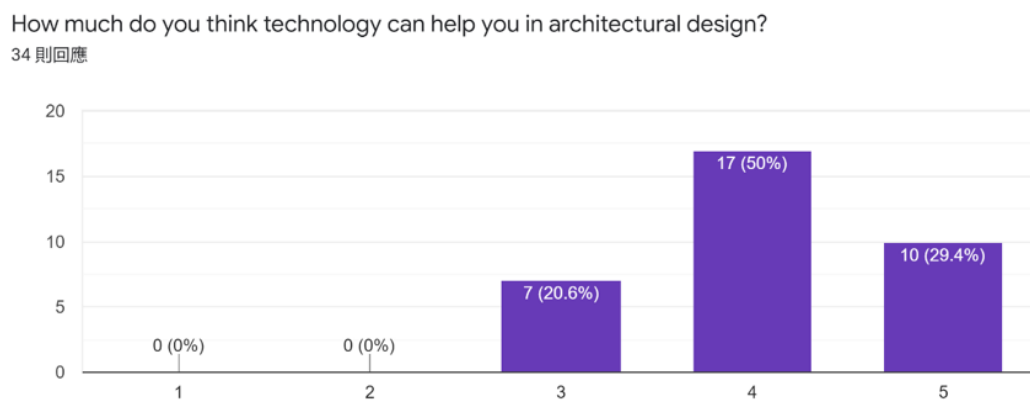


Figure 24. Most students agreed that technology can help them in architectural design (1 = Least, 5 = Most)



Figure 25. Most students agreed that technology facilitates self-directed learning (1 = Least, 5 = Most)

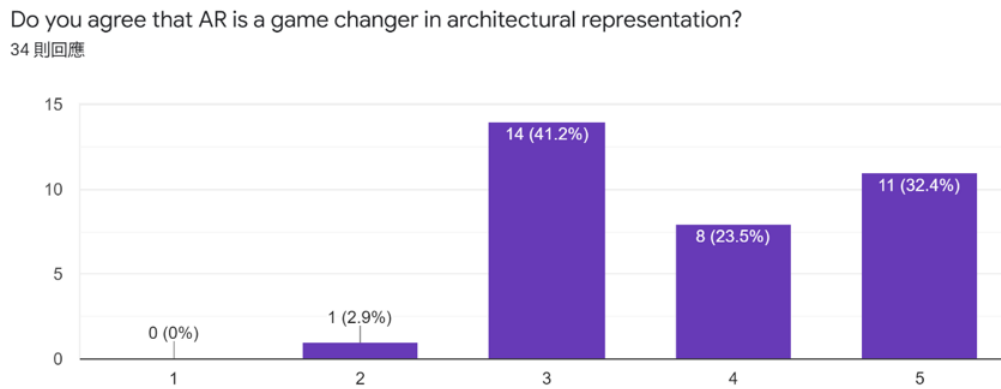


Figure 26. Most students agreed that AR can bring significant changes in architectural representation (1 = Least, 5 = Most)

The survey participants also reported the major issues that may obstruct the effective learning with AR, such as lack of technical support and relevant knowledge, accessibility to specific tools (and hardware), and having to contend with a packed academic schedule in which one is preoccupied by other schoolwork-related demands. For relevant AR knowledge, survey participants expected a range of content covering the technical aspect (i.e. learning the basics, software operation and hardware configuration), communicative aspect (i.e. effective presentation with AR, new methods of conveying messages), design aspect (i.e. AR-informed design process and AR modelling), and application aspect (i.e. real-world application such as restoration of old buildings and AR construction). Overall, survey participants were passionate towards AR learning and the integration with design processes.

DISCUSSION

How to keep students engaged with XR

With reference to the initial perception towards XR applications, it is argued that our initiative has successfully addressed most of the concerns by sharing the necessary knowledge and equipment for XR applications in the existing curriculum. Given the limited time allocated to learning new technology among students (Figure 27), our initiative responded to the paradigm shift in education from instruction-based pedagogy to autonomous self-directed learning, as well as fulfilling the “needs of workforce in industry and economy-oriented occupational fields” (Sen et al., 2018). To maximise engagement with students and fulfill learning outcomes, it is recommended to include XR learning as fundamental knowledge in core courses. More cycles of T&L activities shall be conducted to popularise XR application in school and enhance the sense of technical competence among colleagues and students. Opportunities in integrating with real-world projects should be sought to demonstrate the demand and significance of XR competency in the industry. By implementing XR T&L activities on a regular basis, the central archive can accumulate more reference projects, expand from time to time and gradually enlarge to a library of XR applications for a sustainable mode of self-directed learning.

How much time are you willing to spend on learning AR and other new technology in a week?

34 則回應

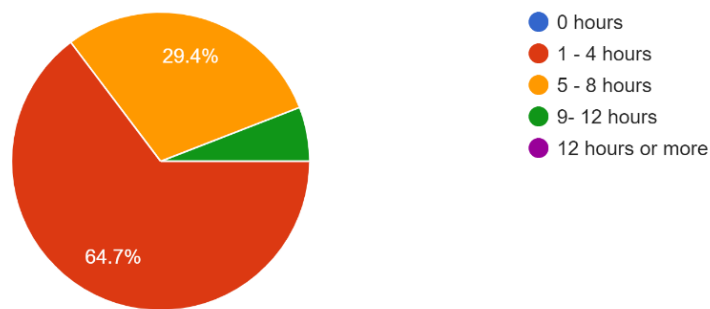


Figure 27. Time allocation to learning AR and other new technology by students

How to change curriculum and syllabus for a more XR driven direction

To plan and alter the architectural design curriculum to further incorporate XR-driven workflows, it is important to consider that such a shift is in the instantiation and continued support of a new culture of teaching and learning, not simply the addition of new hardware, software, and workshops into a teaching programme. This type of investment should be considered longitudinally over several years, and requires additional resource commitment in time, planning, and the reconsideration of assessment criterion that can absorb mixed methods of presentation across media. Many schools may consider this a chicken-and-egg problem, whereby without sufficient hardware, they cannot practically integrate XR into their teaching and learning programmes.

One major consideration is toward the investment in hardware, against the needs of students and instructors to sufficiently introduce successful XR experiences. This depends considerably on budget-related factors, and can impact the immersive nature of the equipment. Mobile phones and tablets for example, are low-cost alternatives to headsets and supporting computer technology; however, they come at the expense of ‘the novelty effect’, and resolution of virtual experiences. In the future, the costs of XR headsets will likely reduce; however, the cost-to-quality ratio has not yet plateaued, implying that the hardware purchased for XR applications will continue to experience a limited shelf-life and need reinvestment (like the costs and upkeep related to maintaining a computer lab within a school).

The incorporation of tools into the planning process of teaching and learning, as expressed through assignments, projects, and programme development, also requires investment from instructors. In addition to the need for them to gain training and confidence with hardware and software associated with equipment, they need to commit aspects of their term and curriculum planning toward technology exposure, and iterative use for students as practical design activities and projects. This planning should emphasise XR platforms as part of design activities, for digitising, observing, analysing, abstracting, modifying, and synthesising geometry for a student architectural proposal. Communicative and presentation-based activities should be considered as valuable but derivative benefits, and not the primary goal for the adoption of XR.

For students to gain the benefits of traditional, studio-based haptic learning alongside digital processes, programmes should consider providing expanded support for prerequisite courses that specifically target complimentary topics such as computational literacy (programming) and advanced 3D modelling to help boost confidence levels and the immediate learning curves associated with novel immersive platforms found in XR. While professionally accredited architecture programmes have their own 3D modelling platforms and

respective computational interfaces, this can be generalised to more open-source tools, such as Unity, and programming languages such as Python. These offer practical interfaces, widely available learning resources, while providing industry standards in quality and transferability.

The goal of integrating XR into architectural education is to ultimately upgrade and prepare students for the post-digital economy that will require them to display confidence and virtuosity when exposed to new tools for design, construction, analysis, and communication with industry. Students should consider XR as part of an expanded toolkit that they can call upon for appropriate and effective use based on the specifics of their ideas, design position, and proposal.

CONCLUSION

This study showcases the current exposure of XR at the School of Architecture at CUHK. XR technology has been perceived as an immersive environment in which students and instructors can communicate beyond existing forms of architectural representation. This immersion and form of representation highlights the affordances of XR that contributes to their learning, as the largest impact of XR in architectural education. It was observed that XR can create new opportunities for students that allow them to symbiotically utilise physical and digital space for exploration, learning and communications. In spatially-driven disciplines such as architecture and design, this enriches learning by reconsidering media, typically regarded as a final output device, and adopting it for active, immersive, and design exploration. Students can subsequently understand and demonstrate the results of their work as parameter- and range-based solutions, rather than a finite solution.

It is important to keep our students engaged with rapidly advancing XR technologies and innovations to remain competitive in the ongoing international debate. This will equip them with the capacity to become pioneers, global players, and leaders in this emerging technology and the wider realm of technology integration itself.

As Stewart Brand frames it, “Once a new technology rolls over you, if you're not part of the steamroller, you're part of the road” (Brand, 2010).

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ENDNOTE

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