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CHAPTER 08

Architecture Education in the Metaverse: Opportunities and Challenges

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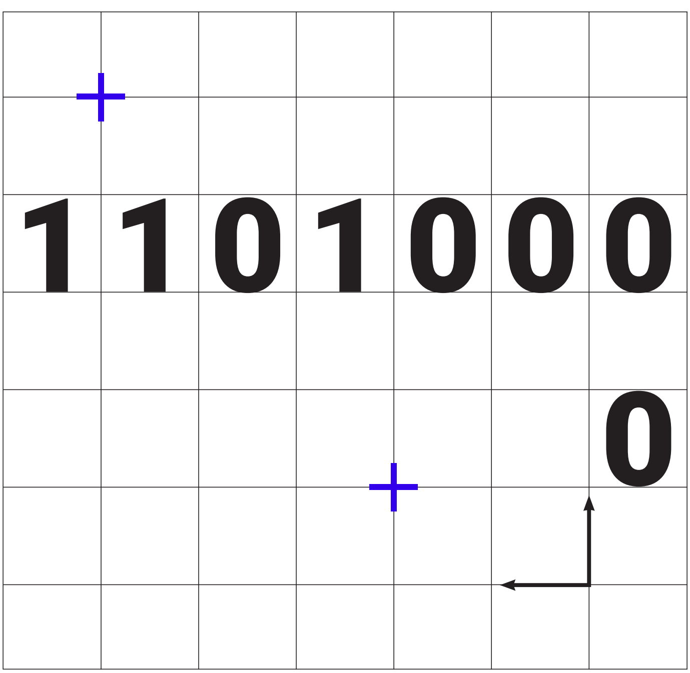

Introduction

For almost 40 years, artificial intelligence (AI) has been used in education for several purposes, including

(a) tracking students' progress, difficulties, and errors,
(b) assisting and grading writing assignments, and
(c) integrating fully immersive educational experiences ***(UNESCO, 2023; Wang J., et al., 2023).***

It seeks to replicate how humans receive information and employ computer skills to handle enormous amounts of data ***(Reiners, D., et al., 2021).*** The use of Extended Reality (XR) technology helps to improve students' performance and the educational experience. ***(Wang P., et al., 2024; Crolla, K. et al., 2024),*** it is characterized as computer-generated settings that merge the physical and virtual worlds, allowing students to interact with both the environment and virtual objects ***(Milgram, P., et al., 1995).*** The virtual world of Metaverse is a three-dimensional virtual world full of real-life avatars ***(Guo, X., et al. 2021).*** Metaverse environments are interactive digital representations in three or four dimensions. They may be accessed through many devices, including personal computers PCs, laptops, mobile apps, smart TVs, and VR headsets. In the future, architectural spaces may also serve as interfaces with panoramic screens or holographic projections ***(Schumacher, P., 2022).*** Metaverse has the ability to influence future educational trends and drive significant educational transformation ***(Guo, X., et al., 2021).***

The aim of this study is to explore the possibilities of implementing Extended Reality technology in architecture education and if it has caused a substantial shift in teaching and learning methods. It analyses and discusses the relevant challenges and opportunities of using Metaverse -based Learning. The methodology depended on two approaches; qualitative approach to understand and discover the immersive technology application in the architecture education. In addition to a quantitative approach by using a questionnaire to collect data about the extended reality technology adoption and familiarity in the Middle Eastern architecture education. The results show that 35% of architecture students, faculty, and professionals in the Middle East have very familiar with extended reality (XR) technologies. Finally, this study presents recommendations for future framework.

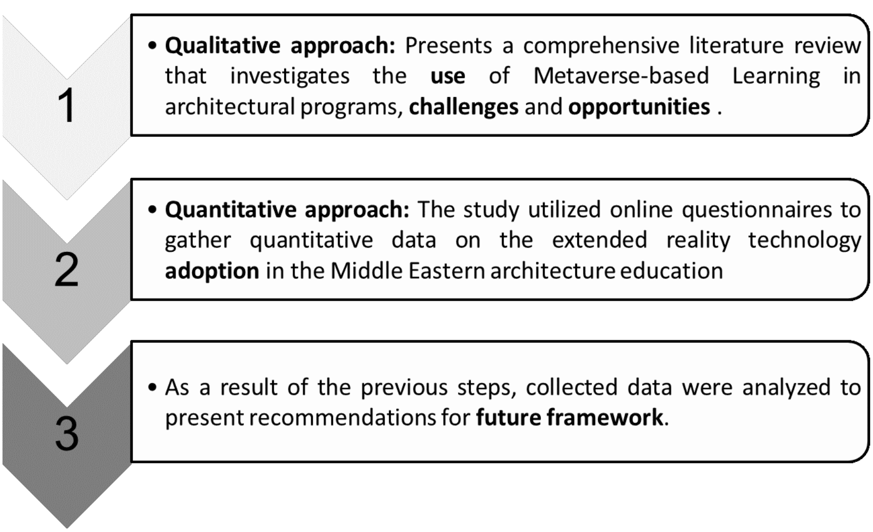

Figure 01: A graphical figure representing the theoretical framework and methodology ***(Researcher, 2024)***

The main objective of this research aims to address the following questions:

Q1: Which XR tools and applications are currently being integrated into architecture curricula across the region?

Q2: What are the benefits and challenges of using these technologies in classrooms?

Q3: What is the level of familiarity and experience that architecture educators in the Middle?

Q4: What are strategies required to enhance the utilization of XR technologies in Middle Eastern architecture programs?

Teaching students using the traditional techniques, where there is only one mode of communication, is no longer successful ***(Wang J., et al., 2023).*** Distance learning existed before the COVID-19 pandemic, and certain platforms were regarded as requirements rather than options. Significant alterations in management education were brought during the COVID-19 pandemic, encompassing the integration and application of digital technology in the educational process. ***(Ratten, V., 2023).*** Technology is transforming the education scene. Thus, extensive and sustained expansion in education requires a broader application of current information technology ***(Guo, X., et al., 2021).***

Extended Reality (XR) for Immersive Experiences

The origins of extended reality can be traced back to the 1800s, when “stereoscopes,” or binocular-like devices, induced viewers to believe they were watching pictures in three dimensions. Over a century later, the same XR technology would serve as the foundation for an even more immersive experience dubbed “Sensorama,” which provided viewers with a visual, auditory, and even olfactory tour of a Brooklyn motorcycle ride ***(Marr B., 2021).*** The field of Information and Communication Technologies (ICT) and Human-Computer Interaction (HCI) is changing as a result of the introduction of new design paradigms that alter how we interact with digital data ***(Partarakis, N., et al., 2024).*** Computer graphics and wearable technology generate both virtual and actual settings.

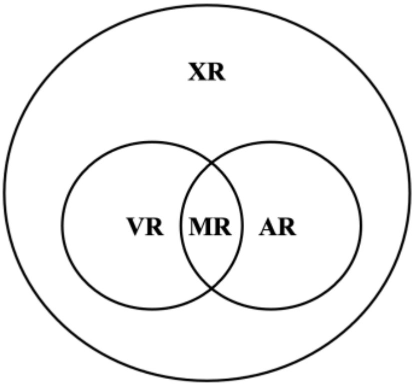

Figure 02: Venn diagram representing XR and its components ***(Sharma, R. 2021)***

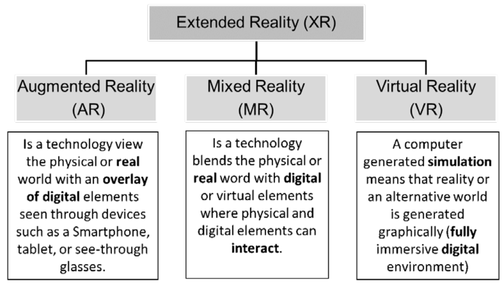

Figure 03: Description of various components in XR ***(Researcher, 2024)***

Virtual Reality (VR)

Guo et al., (2021) define virtual reality as "The complete replacement of the real environment with a digitally produced one". It immerses viewers in a fully virtual environment created using computer technology ***(Sharma, R., 2021)*** and relies on Head-Mounted Displays (HMDs) to deliver a virtual world that totally substitutes the actual world ***(Calvet, L., et al., 2019; Wang J., et al., 2023).*** Its "3I" attributes include immersion, interactivity, and imagination.

VR has been used in education and has demonstrated considerable promise for stimulating instructional change and creativity in fields like as preschool education, physics experimental teaching, geography experimentation, medical training, and art and design ***(Guo, X., et al., 2021).*** Virtual reality technology allows for importing building models at 1:1 size onto displays through their glasses while wearing a head-mounted display ***(Wang J., et al., 2023).***

Augmented Reality (AR)

Augmented reality (AR) is a hybrid of virtual and physical surroundings. AR is a technology that integrates virtual information into the actual world to create an interactive experience ***(Guo, X., et al., 2021).*** It enriches the user's physical presence by overlaying visuals, movies, or other content over the surrounding area ***(Sharma, R., 2021; Wang J., et al., 2023).*** Virtual features are superimposed on a real-world environment as seen through a smartphone, tablet, or see-through glasses ***(Calvet, L., et al. 2019).*** AR in science lectures can help students grasp complicated subjects by providing three-dimensional representations of previously unseen and difficult-to-visualize situations ***(Guo, X., et al., 2021).***

Mixed Reality (MR)

Mixed reality (MR) is a technological concept that enables the coexistence and real-time interaction of virtual information and the physical world. This creates a novel visual experience that incorporates both real-world aspects and virtual items ***(Wang J., et al., 2023).***

MR uses infrared scanning technology on a head-mounted display to integrate virtual content into the real world ***(Sharma, R. 2021).*** This enables educators and experts from a range of fields to instruct students in professional skills in a genuine context ***(Guo, X., et al., 2021).*** Virtual Reality (VR) and Augmented Reality (AR) are now the most widely used applications, while Mixed Reality (MR) is gradually creating new ones ***(Wang J., et al., 2023).***

The 3Rs (VR, AR, and MR) vary in terms of their interaction capabilities. VR offers one-way interaction, AR offers one-way and two-way engagement, and MR allows for two-way interaction between users and virtual and actual worlds ***(Wang J., et al., 2023).***

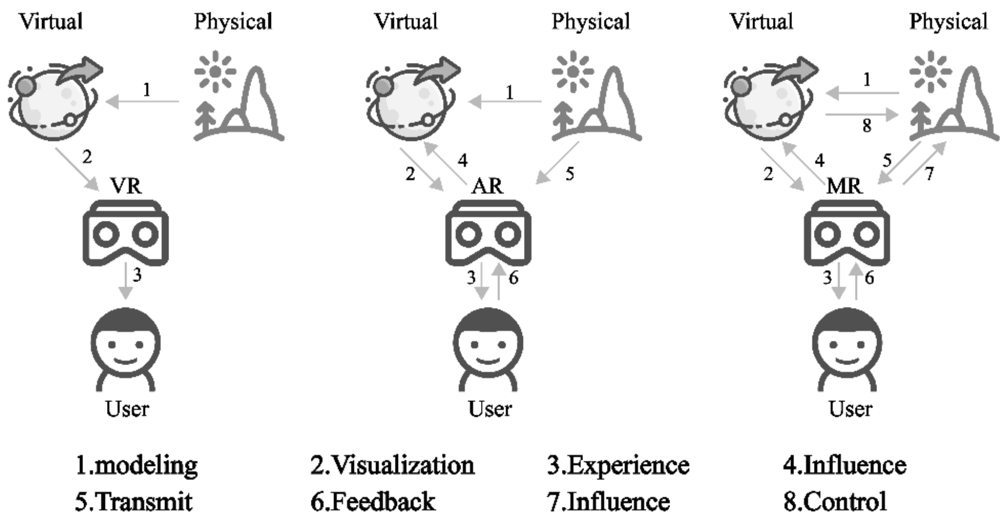

Figure 03: Technology interaction capability for the 3Rs
(Wang J., et al., 2023)

Potential applications of XR in Architectural Education

The rising usage of computerized and advanced technologies has fundamentally changed architectural and infrastructure design techniques, resulting in a closer relationship between both the physical and digital environments ***(Schumacher, P., 2022).*** XR technology is revolutionizing the architecture education methodology by shifting it from a "teacher-centred" approach to a "student-centred" one. This paradigm shift signifies the emergence of an active teaching style to replace the traditional passive teaching technique ***(Wang J., et al., 2023).***

Holographic Lectures for remote Instruction and Mentoring

- Virtual Classrooms: Architecture students are no longer bound to traditional classrooms or video conferencing. Instructors appear as 3D holograms ***(Nermine, F., et al, 2023).***

- Personalized Feedback: Instructors can offer personalized feedback and guidance to students by annotating their virtual design projects and engaging in real-time discussions within the Metaverse.

- Global Collaboration: Interact with larger-than-life holograms of renowned architects and industry experts, engaging in dynamic discussions and immersive demonstrations that redefine the learning experience ***(Abhari, M., et al., 2021).***

Integrated XR into Design Studios and Workshops

- Students visualize and interact with complex 3D models by immersing themselves in virtual or augmented environments, they can gain a deeper understanding of scale, proportion, and spatial relationships ***(Nermine, F., et al, 2023; Wang J., et al., 2023).***

- These immersive experiences help students identify design flaws, test alternative solutions, and refine their concepts more effectively than traditional 2D representations ***(Abhari, M., et al., 2021).***

Site Visits and Real-World Environments for Architectural Projects

- XR technologies allow architecture students to simulate real-world environments and test their designs in immersive, true-to-life settings by overlaying 3D models onto the actual site or generating a virtual replica ***(Crolla, K. et al., 2024).***

- Students can better understand how their concepts will integrate with the surrounding landscape, climate, and infrastructure. Nevertheless, the current state of VR technology is insufficient for providing realistic tactile simulation of materials, necessitating more advancement***s (Wang J., et al., 2023; Crolla, K. 2024).***

Virtual Simulation for Building Systems

- Architecture students in the Metaverse harness the power of Building Information Modeling (BIM) to digitally design, simulate, and collaborate on complex building projects ***(Keying, Z., 2024).***

- BIM software allows them to create comprehensive 3D models, integrating structural, mechanical, and electrical systems into a cohesive virtual prototype ***(Abhari, M., et al., 2021).***

- Architects may utilize extended reality (XR) technology to construct immersive design environments. This enables clients, stakeholders, and designers to engage with and experience the proposed design in a realistic and captivating manner. Consequently, this can result in more informed decision-making and enhanced design outputs ***(Crolla, K. et al., 2024).***

Sustainable Development & Energy-Efficient

- Leverage renewable energy sources like solar, wind, and geothermal power to create virtual buildings with a low carbon footprint ***(AlQallaf, N., et al., 2022).***

- Design virtual buildings using sustainable materials, recycled, and biodegradable materials that have minimal environmental impact ***(Abhari, M., et al., 2021).***

- Optimize energy consumption for energy efficiency through smart design, advanced thermal regulation, and intelligent lighting and climate control systems. Through the utilization of XR technologies, architects have the ability to generate designs that are more sustainable, efficient, and focused on the needs of the user ***(Crolla, K. et al., 2024).***

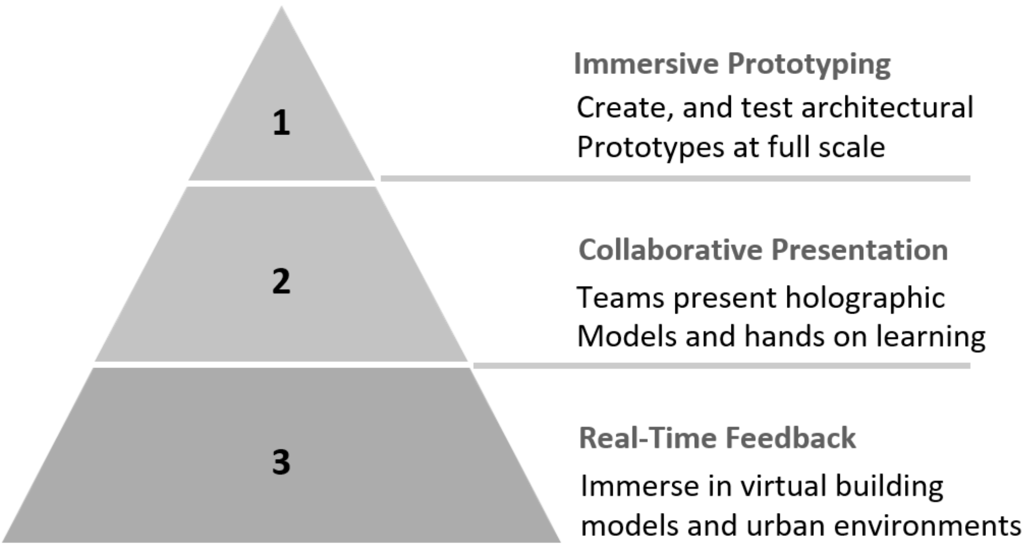

Figure 05: Integrated XR into Design Studios and Workshops ***(Researcher, 2024)***

Challenges and Limitations of Implementing XR in Education

XR technology provides numerous opportunities in architecture design. Designers can have access to extensive data and viewpoints via virtual experiences, architectural ecosystem visualization, BIM integration, and exact environmental simulations, potentially directing the architecture field toward sustainability. Despite existing cases demonstrating the great potential of XR technology, additional research, and practical implementations are necessary for understanding its application in education in architecture and dealing with related design problems ***(Keying, Z., 2024).***

The widespread implementation of XR in architecture education encounters substantial barriers. The challenges encompass a disparity in abilities between students and instructors, the difficulty of creating appropriate simulation and experimental settings to meet specific educational requirements, and the intricacies of incorporating new technologies into conventional curriculum ***(Crolla, K. et al., 2024).***

Institutional Challenges

XR has the potential to act as a transforming tool in education. Furthermore, it emphasizes the significance of tackling financial, technological, and infrastructural obstacles in order to enable effective implementation ***(Skola, F., et al., 2024).***

- Compatibility Challenges: Achieving seamless interoperability between various Metaverse platforms and existing educational systems remains a technical and logistical hurdle ***(Nermine, F., et al, 2023).***

- Technical Expertise: Effectively training educators to integrate Metaverse-based learning into their teaching practices and overcoming resistance to new technologies can be complex ***(Skola, F., et al., 2024).***

- Institutional Adoption: Integrating Metaverse-based approaches into established architectural curricula can face resistance and the need for effective pedagogical strategies ***(Crolla, K. et al., 2024).***

- Cost Considerations: Equipping design studios and classrooms with Metaverse hardware and software can be a significant investment for educational institutions ***(Skola, F., et al., 2024; Crolla, K. et al., 2024).***

Students Challenges

- Equitable Accessibility: Ensuring virtual learning spaces are accessible to all students, including those with disabilities, is crucial but can pose technical and design challenges ***(Wang J., et al., 2023).***

- Health and Safety Concerns: Long-term usage of virtual reality (VR) headsets can cause concerns including motion sickness, strain on the eyes, and physical pain, which require careful handling and mitigation processes ***(Ziker, C., et al., 2021).***

- Infrastructure Barriers: Reliable high-speed internet, robust computing power, and suitable spaces for XR experiences are often lacking in many educational settings.

- Extensive training: Absence of structured technical instruction and the need for skill in rapidly generating virtual environments ***(Wang J., et al., 2023)*** The necessity for extensive training programs to provide instructors and students with the essential expertise to incorporate XR into their work processes ***(Crolla, K. et al., 2024).***

- Ethical Considerations: Addressing concerns around data privacy, online safety, and the potential for digital divides in Metaverse-based education ***(Partarakis, N., et al., 2024).***

Material and Methods

To attain the research goal, qualitative and quantitative methodologies were applied. Research publications on XR applications in architectural education were reviewed and the following procedures were taken:

- Literature review to investigate the use of Metaverse-based Learning in architectural programs, challenges and opportunities.

- Data collecting through online questionnaires to gather quantitative data on the extended reality technology adoption in the Middle Eastern architecture education

- As a result of the previous steps, collected data were analysed to present recommendations for future framework.

Study Context

The use of extended reality (XR) technology in architectural education in the Middle East is still relatively nascent, but gaining momentum. While some pioneering institutions have integrated immersive tools into their curricula, the overall integration remains limited and uneven across the diverse higher education landscape.

Purpose of the Questionnaire

1. Gauge Familiarity with XR: The questionnaire aims to assess the level of familiarity and experience that architecture educators in the Middle East have with extended reality (XR) technologies.

2. Understand Current Adoption: It will explore the extent to which XR tools and applications are currently being integrated into architecture curricula across the region.

3. Identify Barriers and Needs: The survey will also uncover the key challenges and resource requirements for broader adoption of XR in architecture education.

4. Inform Future Strategies: The insights gathered will help shape strategies to enhance the utilization of XR technologies in Middle Eastern architecture programs.

Participants Demographics

- The questionnaire was designed using Google Forms, A 5-point scale was used for the Likert-scale.
- 266 respondents were received; descriptive statistics of the data was processed.
- This mix of perspectives provides a holistic understanding of extended reality technology adoption in the Middle Eastern architecture education landscape.

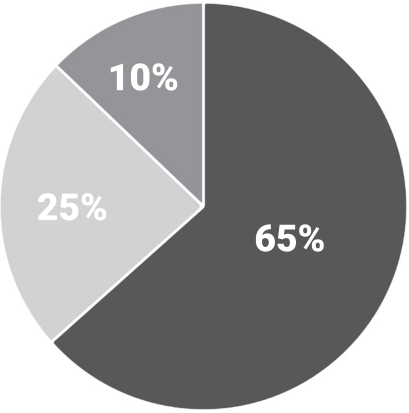

Figure 06: Participants Demographics distribution ***(Researcher, 2024)***

Results:

Familiarity with Extended Reality Technology

The survey results show that the majority of architecture students, faculty, and professionals in the Middle East have at least some familiarity with extended reality (XR) technologies, with 35% reporting being very familiar and 45% somewhat familiar. However, 20% indicate they are not familiar with XR, highlighting the need for increased awareness and educational efforts in this field.

Level of XR Integration in Architecture Coursework

- The survey results indicate that extended reality (XR) technologies are most widely adopted in architecture design studios, where approximately 35% of courses utilize these immersive tools.

- XR integration is also significant in BIM (Building Information Modeling) courses, with nearly 22% of programs incorporating these technologies.

- However, the adoption rate remains relatively low in other core architecture subjects, such as architectural history (8%) and construction management (15%), highlighting the need for a more holistic integration of XR across the curriculum.

Level of Familiarity	Level of Familiarity
Very Familiar	35%
Somewhat Familiar	45%
Not Familiar	20%

Table 01: Familiarity with Extended Reality Technology
(Researcher, 2024)

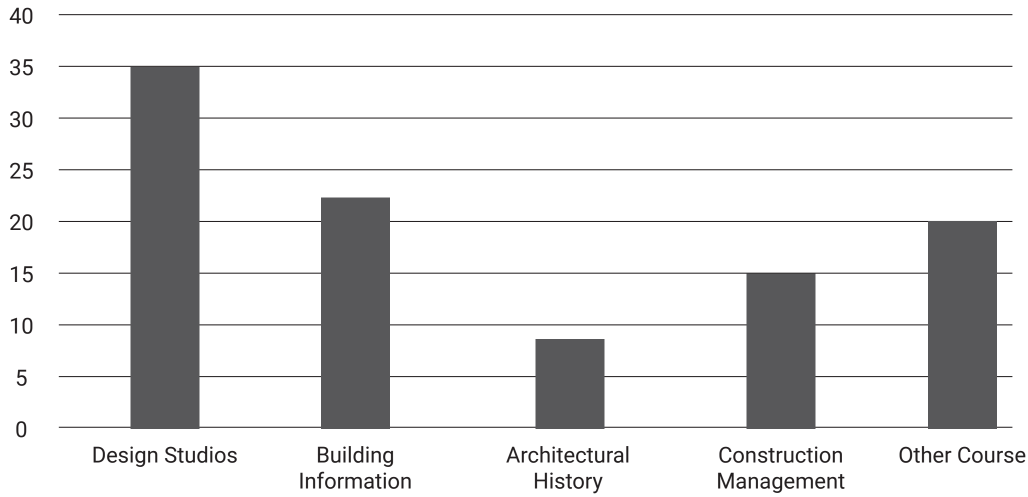

Figure 07: Level of XR Integration in Architecture Course work (Adoption rate)
(Researcher, 2024)

Conclusion:

An examination of past research reveals that as the Metaverse evolves, architectural education will endure substantial changes. Seamless virtual collaboration, AI-powered design tools, and limitless creative expression will change the way students learn, create, and experience the built environment. These technologies create a virtual (three-dimensional) environment in which students can practice and develop abilities in situations that would be difficult or impossible to cope with in reality. ***(Partarakis, N., et al., 2024).***

There is a wide range of software and gadgets accessible, and it is vital to assess and compare them to find the best one. Furthermore, XR systems have serious accessibility issues that must be addressed with both hardware and software. Many experiences need entire 360° movement and motion controller input, yet lack accessibility features to enable a larger range of users ***(Ziker, C., et al., 2021).***

According to Partarakis, cross-disciplinary approaches have the ability to improve the design process by guaranteeing that interfaces are psychologically, morally, and technologically sophisticated ***(Partarakis, N., et al., 2024).*** In contrast, virtual educational settings cannot express the cognitive and emotional sensations of participation, gestures, co-presence, body language, and social contact. According to Khukalenko, the usefulness of VR may vary by field, and teachers' viewpoints in specific subject areas may produce intriguing findings.

Moreover, there are some challenges and limitations of Implementing XR in Education for students' health after utilizing XR technology for a lengthy period of time. As Ziker pointed out, the encompassing nature of VR headgear may create inconvenience or dangers for any students since they lose total control and visibility over their body. It might be challenging to keep students focused when utilizing technology. As a result, students who are working on a worksheet or workbook may benefit from AR while staying on schedule with their studies ***(Ziker, C., et al., 2021).***

Due to ongoing technological advancements, such as enhanced hardware performance, reduced costs, and progressively developed software solutions, XR technologies are gradually becoming more prevalent and easily accessible ***(Crolla, K. et al., 2024).*** Architectural curricula will deeply integrate Metaverse technologies, enabling students to design, prototype, and simulate their ideas in fully immersive, real-time virtual spaces. This boundless creativity paves the way for a new era of innovative, sustainable, and dynamic virtual architecture.

Strategies for Effective Integration of XR in Education

- Dedicated XR Spaces: Establish dedicated XR labs and studios within architectural institutions, equipped with the latest hardware and software, to facilitate hands-on exploration and experimentation by students and faculty.

- Faculty Training: Invest in comprehensive training sessions to equip faculty with the skills and confidence to seamlessly incorporate XR into their teaching methods and course activities.

- Curriculum Adaptation: Carefully map out how XR can be integrated into existing course structures and learning objectives, ensuring a cohesive and meaningful integration across the architectural education program.

- Industry Partnerships: Foster collaborations with architecture firms and technology companies to stay up-to-date on industry trends, access the latest XR tools, and provide students with real-world, immersive design experiences.

The use of XR in education need the support and resources of an interdisciplinary community of dedicated experts from education, government, and business who will work together to overcome the present challenges to adoption.

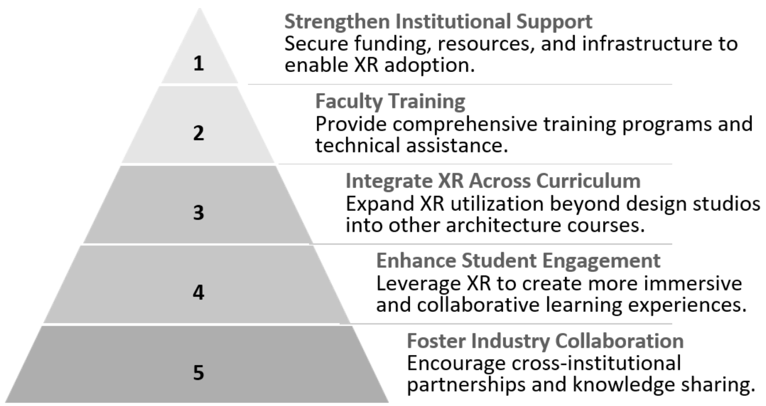

Figure 08: Future Roadmap for Incorporating XR in Architecture Education
(Researcher, 2024)

Scope and Limitations

Although the study offers compelling insights, it is crucial to recognize its limits. The study's sample size was restricted to 266 participants from Middle Eastern countries which may affect the generalizability of the findings.

Further Research

Establish framework for integrating XR technologies into architectural curricula for studio courses by using Participatory Action Research (PAR) methodology.

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Conflict of Interests

The Author declare that there is no conflict of interest.

References

Abhari, M., Abhari, K., Drinkwine, M., & Sloan, J. (2021). Extended Reality (XR) applications in architectural practice: Towards a development framework. HCI International 2021 - Late Breaking Papers: Multimodality, eXtended Reality, and Artificial Intelligence, The 23rd HCI International Conference, Virtual Event, July 24–29, 2021, Proceedings, 185–196. https://doi.org/10.1007/978-3-030-90963-5_15

AlQallaf, N., Bhatti, S., Suett, R., Aly, S. G., Khalil, A. S. G., & Ghannam, R. (2022). Visualising climate change using extended reality: A review. In ICECS 2022: 29th IEEE International Conference on Electronics, Circuits & Systems, Glasgow, UK, 24–26 October 2022. https://doi.org/10.1109/ICECS202256217.2022.9970808

Calvet, L., Bourdin, P., & Prados, F. (2019). Immersive technologies in higher education: Applications, challenges, and good practices. Proceedings of the 2019 3rd International Conference on Education and E-Learning, 95–99. https://doi.org/10.1145/3371647.3371667

Crolla, K., Song, J., Bunica, A., & Sheikh, A. T. (2024). Integrating extended reality in architectural design studio teaching and reviews: Implementing a participatory action research framework. Buildings, 14(1865). https://doi.org/10.3390/buildings14061865

Guo, X., Guo, Y., & Liu, Y. (2021). The development of extended reality in education: Inspiration from the research literature. Sustainability, 13(24), 13776. https://doi.org/10.3390/su132413776

Keying, Z. (2024). Innovative applications of XR in architectural sustainability: Current trends and future prospects. Academic Journal of Science and Technology, 10(3), 69–73. https://doi.org/10.54097/nfcfab89

Marr, B. (2021). Extended Reality in Practice. John Wiley & Sons Ltd. ISBN 9781119695172.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented reality: A class of displays on the reality-virtuality continuum. SPIE, 2351, 282–292. https://doi.org/10.1117/12.197321

Nermine, F., Rowaida, R., Samy, A., & Ghada, H. (2023). Virtual reality: A paradigm shift in architecture and urban design education. In ONCON2022—1st Annual Online Conference of IEEE Industrial Electronics Society (IES). https://doi.org/10.1109/ONCON56984.2022.10126564

Partarakis, N., & Zabulis, X. (2024). A review of immersive technologies, knowledge representation, and AI for human-centered digital experiences. Electronics, 13(2), 269. https://doi.org/10.3390/electronics13020269

Ratten, V. (2023). The post-COVID-19 pandemic era: Changes in teaching and learning methods for management educators. The International Journal of Management Education, 21(2). https://doi.org/10.1016/j.ijme.2023.100777

Reiners, D., Davahli, M. R., Karwowski, W., & Cruz-Neira, C. (2021). The combination of artificial intelligence and extended reality: A systematic review. Frontiers in Virtual Reality, 2, 721933. https://doi.org/10.3389/frvir.2021.721933

Schumacher, P. (2022). The metaverse as an opportunity for architecture and society: Design drivers, core competencies. Architectural Intelligence. https://doi.org/10.1007/s44223-022-00010-z

Sharma, R. (2021). Extended reality: Its impact on education. International Journal of Scientific and Engineering Research, 12(12), 247–251. ISSN 2229-5518.

Skola, F., Karanasiou, A., Triantafillou, M., Zacharatos, H., & Liarokapis, F. (2024). Perceptions and challenges of implementing XR technologies in education: A survey-based study. In Auer, M. E., & Tsiatsos, T. (Eds.), Smart Mobile Communication & Artificial Intelligence, Proceedings of the 15th IMCL Conference – Volume 2, Springer, Cham. https://doi.org/10.1007/978-3-031-56075-0_28

UNESCO. (2023). Technology in education. UNESCO 2023 Global Education Monitoring Report. Institute for Education Planning (IIEP). https://www.unesco.org/gem-report/en/technology

Wang, C., Chen, X., Yu, T., Liy, Y., & Jing, Y. (2024). Education reform and change driven by digital technology: A bibliometric study from a global perspective. Humanities and Social Sciences Communications, 11, Article no. 256. https://doi.org/10.1057/s41599-024-02717-y

Wang, J., Ma, Q., & Wei, X. (2023). The application of extended reality technology in architectural design education: A review. Buildings, 13(12), 2931. https://doi.org/10.3390/buildings13122931

Ziker, C., Truman, B., & Dodds, H. (2021). Cross-reality (XR): Challenges and opportunities across the spectrum. In Innovative Learning Environments in STEM Higher Education (pp. 55–77). https://doi.org/10.1007/978-3-030-58948-6_4