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Model Proposal for Integrating VR/AR Technologies in Building Construction Project in Architecture Education During Covid-19

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Abstract

Information technologies including VR/AR; by providing an immersive environment, contain wide range of innovative opportunities in architecture education, particularly for the Covid-19 pandemic that forced online education. Recent literature reviews show the increase on the adaptation of VR/AR technologies in architecture education, since it improves learners' outcomes and tutors-learners' interactions. However, implication of these technologies is frequently seen in design studios, whereas building construction education continues mostly its traditional approach. The study aims to close the gap in this area by proposing a model to integrate VR/AR technologies in building construction education by the assistance of BIM tools in order to boost the effectiveness. This model is developed for the building construction project course, shows step by step integration of related tools and technics to obtain the learning outcomes efficiently during online education in Covid-19 Pandemic. Considering the pandemic conditions, the proposed model involves creative usage of VR/AR tools in terms of distance learning.

Keywords: (VR)Virtual Reality; (AR) Augmented Reality; Building Construction; Distance Architecture Education, Covid-19 Pandemic.

1. Introduction

The urgent need for adaption of information technologies in architectural education that based on Virtual Reality (VR) and Augmented Reality (AR) is growing rapidly as a result of Covid-19 Pandemic which is the worst healthcare disaster for the last century. Specifically, in today's conditions, distance learning is becoming the main method of education in universities in all over the world. In architectural education, there are some studies about adapting VR – AR technologies on design studios. Particularly, digital education platforms support collaborative learning and co-design situations in which students develop a mutual understanding of the given design problem and a shared goal, and achieve this goal through working and learning together on the design artifact (Gul, 2015). On the other hand, adaptation of these technologies on courses about building technology and construction in architecture education is limited; mostly, the traditional methods are being used commonly. Traditional methods are not fully sufficient for students to understand new construction techniques. There is a necessity of integration recent technologies into building construction courses in order to increase students' knowledge and interactions. As Gul (2015) mentioned teaching approach that depends on the understanding of students' interaction while considering the students as the active learners, is the key element to achieve effectiveness on building construction courses.

While adapting VR – AR technologies on building construction courses, in order to improve students' learning outcomes and collaborative working of students, Building Information Modelling (BIM) is selected in this study as a suitable tool. One of the biggest advantages of BIM-based VR is the ability of the model to reflect real-time changes and have a realistic-feeling experience. In particular, cooperative systems as BIM, have nowadays become suitable visualization and interaction platforms, while the online education of construction engineering is still lacking (Wang, 2018). However, there are limited attempts recently to incorporate them in construction education. In addition, to extend prevalence of VR usage; Desktop-based VR is becoming more useful and essential. As the study by Wang (2018) about construction related education, involves the distribution of publications characterized by technology and publication year that shows the most commonly adopted VR systems in the literature are BIM-based VR and Desktop-based VR, accounting for 47% and 26%, respectively. According to Horne and Thompson (2015), VR and AR technologies are useful in education from these perspectives: ability for students to do and practice interactively in 3D immersion environments and the availability of applications related to all built environment issues. Achieving VR – AR integration with BIM tools results in monitoring a proper building life cycle that contains work sets of concept design and construction projects and schedules. The aim of this study is to have contemporary and holistic approach on architecture education by proposing a VR – AR integrated building construction project model.

2. Materials and Methods

The study aims to introduce a model in order to integrate sufficiently and effectively VR – AR technologies into building construction project course. There are various technologies and tools about these technologies. In this

study, best solution to have maximum level of students' interactions is considered. In the meantime, the model involves selections of tools and specifying the methods to be used with an order.

VR is defined as a creation of a virtual environment by usage of technology, while AR is placing digital and virtual objects into the real environments (Figure 1).

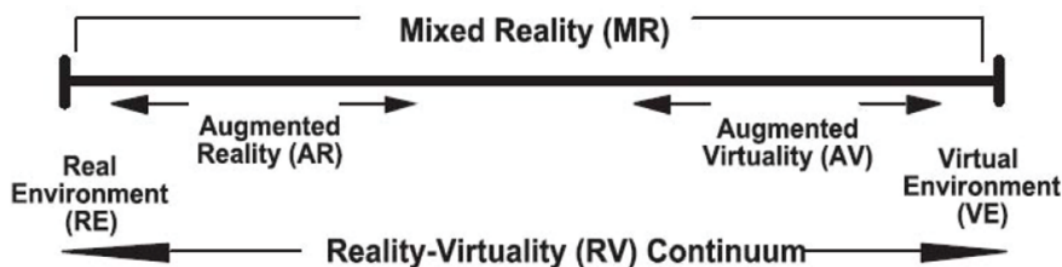


Figure 1. Taxonomy of Mixed Reality (Milgram & Kishino, 1994)

VR is a computer-generated simulation in which a person can interact within an artificial three-dimensional environment using electronic devices, such as special goggles with a screen or gloves fitted with sensors. On the other hand, AR is the rendering of digital images or data onto real-world objects with the use of digital visual elements, sound, or other sensory stimuli delivered via technologies like smart phones, tablets, headsets, helmets. In this study, due to the Covid-19 pandemic conditions which forced education into distance learning; headsets and handsets of VR are not selected to use in terms of impracticality.

In this study, Desktop based VR which is demonstrated with SimLab software, is chosen through laptops or PCs screens without any specific equipment to support. It is based on students' abilities to understand space in 3D virtual world experience by using standard mouse and keyboards. SimLab software tool of VR Viewer in Desktop mode, aims to achieve virtual environment effect in building construction project course.

BIM-based VR relies on the Revit 3D BIM model is emphasizing on the data binding and connections which are related about building material types, structural system, site information, meantime it is possible to simulate construction processes and operations as well as visualization. Students can compose BIM data in immersive visualization environment and analyse information to develop effective building construction in real time. Autodesk Revit software is a tool to create BIM models which will be simulating base for VR and AR technologies. Autodesk Revit enables quick move from 2D drawing and 2D thinking to 3D drawings and scenarios. Another crucial point that students have to demonstrate is environmental analysis part of Autodesk Revit. Autodesk Revit sun path analysis Autodesk Revit Insight plugin, Archidynamics for wind analysis and Synchro for scheduling construction process are planned to make building performance analysis in terms of environmental conditions and material types. BIM-based VR while using Autodesk Revit enables students to interact in a VR environment with building elements. In this simulated artificial environment, students are able to have a realistic-feeling experience.

As mobile devices such as smart phones and tablets are becoming more convenient in education, many applications have been developed to embed AR in mobile devices. One of the stages of AR is implementation of creating QR codes by students. It is a method that increases the practicality of communication between students and tutors as well as between classmates. There are advantages to students especially which they are explaining their projects in distance learning during Covid-19 pandemic. ARCore, Apple ARKit, Free QR Scanner, Kaspersky QR Scanner can be used as mobile devices applications to stimulate AR in the scope of this study. Also, there are desktop QR code generating programmes such as Sketchfab, Qr Code Generator, Kalite Barkod, Qrcodeg to be use in this study. In addition, generating QR codes are recommended in presentations along with 2D and 3D illustrations from Adobe Photoshop and Lumion softwares. Moreover, hand sketching, digital sketching, Sketchup and Autodesk Autocad tools can be used at some stages of the project.

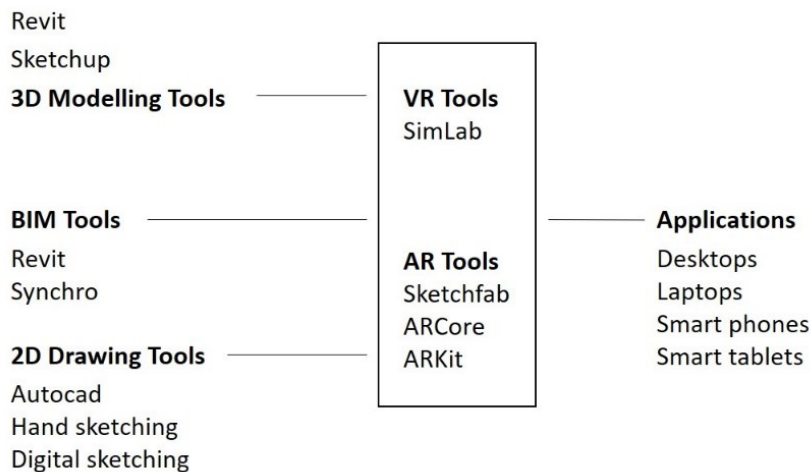


Figure 2. VR – AR tools and workflow (Drawn by authors).

In this study, a systematic approach is adapted into building construction project by scheduling weekly to determine when to use proper tools which are mentioned above. The scenario of the building project is prepared, and requirement list is given to students.

As result of the distance education due to the Covid-19 pandemic, Zoom Video Conferencing Platform is selected as an online platform for the weekly live classes. The tutors and students are using ‘screen sharing’ option to show and discuss the model and the drawings. Also, with ‘annotate’ option in Zoom, the tutors are capable of to draw, highlight and correct during critics and revisions. In addition to the Zoom platform for the live classes, there is a Moodle-based ‘onlinebeykoz’ as an online information sharing platform. In onlinebeykoz, tutors are uploading presentations, documents, essays, videos for students while students are uploading their works. Furthermore, there are ‘wiki’ and ‘forum’ options that are discussion sections for students and tutors to make brainstorming about the related subjects in order to obtain learning outcomes.

3. Results: Proposed Model

The model is developed for the building construction project course, shows step by step integration of related tools and technics to obtain the learning outcomes efficiently during distance learning in Covid-19 Pandemic.

‘Building construction project’ course aims to develop a technical approach to architectural design and teach detailing in building construction by introducing students the phases and techniques of the preparation of a construction project. Students are expected to gain access to construction industry resources, related directives and laws with regard to design, technical drawing and construction. This course encourages students to translate the theoretical knowledge built up in the Building Science and Technology course series to the structural design of a building.

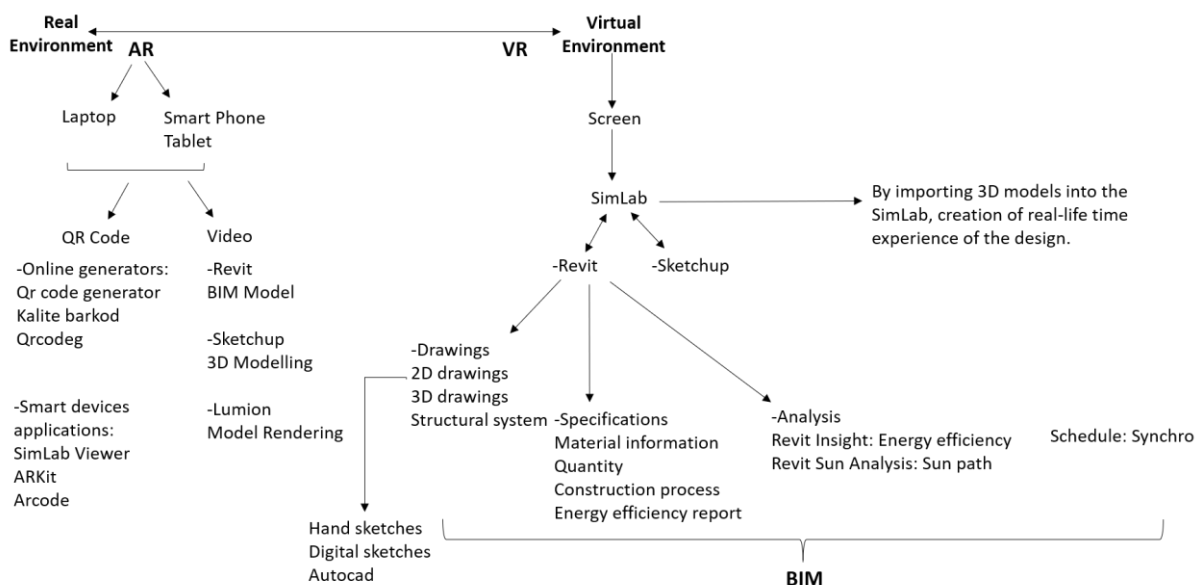


Figure 3. The proposed model for integrating VR-AR technologies with BIM tools (Drawn by authors).

For this purpose, students produce technical drawing documents that will allow the construction of a building as part of the project for 14 weeks schedule. In this direction, the scenario determining the adaptation of VR / AR technologies has been formed and is shown in Table 1. The scenario was created as weekly work to be done, the tool to be used for that study and the output of that work.

The scope of the project is designing an apartment building with 5 floors, approximately having construction area 1500 sqm and consists of different flat types such as 1+1, 2+1 and 3+1. Reinforced concrete or steel can be chosen by the students as building construction structure system. Students are guided about building regulations. The project consists of individual work and assigned real site in Istanbul, Turkey.

For the first two weeks, examination of site data and first ideas of conceptual design in accordance with regulations and site data are expected. In this stage; hand sketching, digital sketching, Autodesk Autocad and Autodesk Revit tools are accepted. As starting from the 3rd week, firstly, preparing plans and sections in 1/200 detail and then 1/100 scale in Autodesk Revit program are schedules. As of the 6th week, obtaining the first simulation with the SimLab software, and by 7th week making decisions such as choosing the joinery systems that affect the elevation drawings by using Autodesk Revit software. In the 8th week, the jury as a midterm is prepared for the students show their works by using Autodesk Revit, Lumion, Adobe Photoshop, with QR Code creation and mobile device applications. Assigning material decisions to wall systems and then floor systems in 1/50 detail for the 9th week is planned. Processing the details that are created in Autodesk Revit; can be transformed in Autodesk AutoCad and specific details can be modelled in SketchUp software. With the final delivery of project work sets including 2D and 3D drawings, illustrations that created through mobile device applications and QR Code generators, and 3D VR environment simulations, the aim of the study is succeeded.

Table 1. Schedule of the model, step by step for each week for building construction project (Composed by authors).

			TOOLS	LEARNING OUTCOMES
week 1	INTRODUCTION			
	VR/AR Technology - BIM Tools - Project Folder (Site informations as AutoCad Files and general reqs)		Syllabus, Lecture Presentation about BIM and VR-AR	Discussions
week 2	Concept Design		Hand Sketches, Digital Sketeches, Autodesk Revit	Site Analysis - Sun Analysis of the Site by Autodesk Revit
	First Sketches - Site Plan and Conceptual Floor Plans			Functional Diagrams, Site Plan and Conceptual Floor Plan Alternatives
week 3	Site Plan	1/500	Autodesk Revit	Site Plan and Floor Plan Drawings with basic Revit Elements and Section Drawings
	Floor Plans	1/200		Sun orientation to be considered.
week 4	Floor Plans with Structural System	1/200	Autodesk Revit	Implementation of Sturctural Loadbearing Frame Elements (Column, beams, etc..)
	Section Drawings	1/200	(architectural ve structural interface together)	Determining the placement of openings
week 5	Floor Plans with Structural System	1/200	Autodesk Revit	Detailing building core system considering the general structural frame system.
	Section Drawings	1/200	(architectural ve structural interface together)	Determining the placement of openings
week 6	Floor Plans and Sections	1/100	Sim Lab	Building 3D Simulation
			DeskTop Mode	
week 7	Plans, Sections, and Elevations	1/100	Autodesk Revit	Principle decisions for the elevations (openings) and roof system.
	Dimensions to be involved.		(Plug In: Insight)	Energy Efficiency Analysis, Elevations: Joinery system, roof systems, sun control elements, etc.
week 8	MID TERM JURY		Revit, Photoshop, Lumion, SimLab,	SHEETS :Site Plan 1/200, Plans-Section-Elevations1/100
			QR Code, Mobile App	VIDEOS :Sun Path Simulation, Walk Through Simulations in Real Time Site
week 9	Wall Systems , Openings	1/50	Autodesk Revit	Building Elenets Detailing (Wall layers and finishing materials)
			(Interface: Architectural)	Elevations: Joinery system, roof systems, sun control elements,etc.
week 10	Floor Systems, Stairs	1/50	Autodesk Revit	Building Elenets Detailing (Floor, Ceiling and Roof layers and finishing materials)
			(Interface: Architectural)	
week 11	Foundation , Roof System	1/50	Autodesk Autocad	Transforming REVIT files into Construction Documents Drawing Set
week 12	1/50 Detailing	1/50	Sketchup	Modelling the details
			QR Code, Mobile App	Defining 3D Layers by AR
week 13	1/20 System Detail	1/50	Sketchup - Lumion - Autodesk Revit Insight	Lumion modelling
			QR Code, Mobile App	Energy Efficiency Analysis, Sun Path Simulation, Walk Through Simulations in Real Time Site
week 14	Quantity Survey		AUTO CAD, Lumion	Quantity Survey Report, Analysis Reports
	Title Sheet preparation		Sim Lab, Syncro, QR Code,	Drawings as Submission Sheet Set, Simulation Videos

4. Discussion

Today, there are great variety of options and technologies to use in architecture education. It is probable to get lost in this diversity of technologies which will end in waste of time and improper building construction details. However, the crucial point is showing the limitations and possibilities of each tool to use in building construction projects. Hence, it is fundamental to prepare a guideline for students and tutors that which tool to implement at what stage, step by step to increase efficiency and effectiveness of the learning outcomes according to architectural curriculum. In order to adapt this model properly, main consideration is introducing these digital tools towards student starting from the very first year. In addition, integration of digital tools between each other and mix usage of hand and digital possibilities should be considered as advantage.

Understanding and designing building construction details and decision- making process on materials and systems are the most difficult stages in architecture education, especially for building construction projects course. Traditional methods of 2D drawings and 3D images does not give the necessary perception of construction to the students, it is not possible to demonstrate for them how real construction is, how building systems are composed

of. On the other hand, it is not practical to experience real construction site during the course for each week. This current situation does not allow students to apprehend the relation between the real system and the drawing. Therefore, it turns into a bottle neck. In order to figure out this bottle neck, VR - AR simulations are the most effective solution, as providing the real time experience in class environment. As a result of distance learning due to the Covid-19 Pandemic, VR – AR headsets and handsets are not involved in this study, because it is not possible for each student to provide this equipment. Desktop based VR mode and mobile based AR tools are easy to access and use for students, as they are involving these technologies in their daily life frequently. Furthermore, integrating daily life application with building construction projects will give fully engagement of students as a significant advantage.

5. Conclusion

The proposed model is composed of tools and their workflows for process of 14 weeks in order to simulate building construction decisions from analysis till preparation of construction documents. Considering Covid-19 pandemic conditions, the proposed model involves creative usage of VR-AR tools in distance learning. Integration of BIM tool within VR – AR, advantages of desktop-based VR and mobile AR applications are involved. It is aimed to have a guideline model for tutors and students to demonstrate the whole building construction process and all systems as solid. In future studies, this model can be adapted other building construction courses. Furthermore, recent developments about 3D printing and robotics will improve this proposed model and will give an opportunity to model physically in 3D as result of integration VR-AR and BIM.

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Conflict of interests

The Authors declare no conflict of interest.

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