The Use of Immersive Virtual Environments (IVEs) For a Collaborative and Interactive Education in the Architectural BIM Design

Jeonghwan Kim*[a], Chi Kwan Chau[a], Seung Hyun Cha[b], Joon-Oh Seo[c], Choongwan Koo[d]

[a] Department of Building Services Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR

[b] Department of Interior Architecture Design, Hanyang University, Seoul, Korea

[c] Department of Building and Real Estate Engineering, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong SAR

[d] Department of Architectural Engineering, Kyonggi University, Suwon, Korea

*Corresponding Author: jeonghwan.kim@polyu.edu.hk

Abstract

Immersive Virtual Environments (IVEs) has emerged as powerful platforms for communication and interactive tool, and has been attracting considerable interest in Architecture, Engineering, and Construction (AEC) industry. Since it is important to address inefficient communication and collaboration between stakeholders throughout the project cycle, IVEs can play an important role by giving all participants a clearer vision of their project with high immersion and intuitive representation of design information, which leads to enhance their ability to make well-informed decisions. However, the curriculum for AEC education in Hong Kong has failed to keep up with global advances in technology. It is still founded on single discipline-oriented, unidirectional and non-project based learning. Consequently, our AEC education is challenged in its capacity to provide students with opportunities for collaboration in multidisciplinary teams, with a limited ability to give them hands-on experience in the use of state-of-the-art technology and to impart practical project knowledge. To address these challenges, this study aims to bring an integrated platform incorporating both IVEs and Building Information Modeling (BIM) into university classrooms. This will provide a unique way of learning, and one that is unlike all other existing media and teaching tools. Using 3D environments incorporating existing BIM technology, students can gain practical experience of any real-world construction problems or virtual situations. A case study have conducted to illustrate the effectiveness of the IVEs, and the preliminary results support the idea that IVEs can enhance students' collaboration and interaction while they facing architectural design problems.

Keywords: Immersive Virtual Environments, Building Information Modeling, Education, Collaboration, Architectural Design

Introduction

The complexity of Architecture, Engineering, and Construction (AEC) projects requires continuous interdisciplinary collaboration between contractors, architects, engineers, clients and project managers, from diverse backgrounds and at widely-distributed locations. Collaboration and communication between stakeholders has been an important issue in the AEC industry, as confirmed in the literature [1-6]. To give all participants a clearer vision of their project and to enhance their ability to make well-informed decisions, it is important to address inefficient communication and collaboration between them throughout the project cycle. In light of this, first, it is important for information to be inter-operable among stakeholders. To effectively support the use of information, organisations need to be able to present their project data in a common interpretable form, which facilitates accurate data exchange between different computing systems and platforms. Thanks to recent technological advances — inclusive of computer modelling, rendering, digital fabrication — in Building Information Modelling (BIM), 3D building models containing precise geometry and relevant data in support of the various activities in AEC projects now have industry-wide implementation. Three-dimensional building models commonly incorporate (but are not limited to) information about geometrical and spatial relationships, quantities and properties of building elements, cost estimates, material inventories and project schedules. Along with the development of BIM technology, IFC — the Industry Foundation Class standard, which is the leading interoperability standard — makes BIM inter-operable so that stakeholders can retrieve any type of data regardless the software they are using. In addition, BIM is a shared knowledge resource for information about a project, constituting a reliable basis for decisions over its life-cycle from conception to demolition.

Second, interdisciplinary collaboration is a prerequisite for the use of BIM technology, which means that project participants must be in frequent communication with all other stakeholders (e.g. owner-designer, designer-engineer, engineer-clients, and so on.). Recently, innovative collaboration technologies have been developed. These technologies include an immersive virtual environments (IVEs) and a variety of advanced computer-aided tools, many of which are now being deployed in AEC projects. The use of IVEs as an alternative form of data representation has become an increasingly attractive option for computer interface designers across a variety of disciplines, including education. It is thought of as an alternative approach because, in an IVEs, users are no longer looking at data on a screen. Instead, they are immersed as active participants within the data. The IVEs can be realistic, as would be the case with models of building interiors through which users walk, or it can be abstract.

Although the ICT has been grown, in many respects, the curriculum for AEC education in Hong Kong still has failed to keep up with global advances. It is still founded on single discipline-oriented, unidirectional and non-project based learning. Consequently, our AEC education is challenged in its capacity to provide students with opportunities for collaboration in multidisciplinary teams, with limited ability to give them hands-on experience in the use of state-of-the-art technology and to impart practical project knowledge. For example, architectural design requires multi-disciplinary knowledge (of structural design; construction materials; plumbing, heating and ventilation; air-conditioning; pipe and gas; mechanical and electrical systems; lighting; hydraulic supply; construction management; time/cost/risk management; town planning and environment, and so on). This knowledge is fragmented into, and implemented by, different departments (such as building service engineering; civil and environmental engineering; and interior design). Even though a capstone/design project involves knowledge taught to students during their time in a department, its application is vested in a limited, single-discipline project. Moreover, AEC-related departments require a BIM component in the curriculum. To meet this requirement, an all-embracing curriculum and interlinked subject teaching across the fields of engineering, design, and science needs to be offered to university students so that they can develop their interdisciplinary know-how.

To address these challenges, this paper presents a framework to bring an integrated platform incorporating both IVEs and BIM into university classrooms. This will provide a unique way of learning, and one that is unlike all other existing media and teaching tools. Using IVEs incorporating existing BIM technology, students can gain practical experience of any real-world construction problems or virtual situations. They will have the opportunity to play an active role in their learning, as outcomes will dynamically change depending on student input. By facilitating the incorporation of 3D immersive virtual environments and BIM into the educational program, we can give students the experience of effective communication and innovative collaboration through the new technology.

Based on the abovementioned issues and challenges, this study proposes:

Basing our specific feasible objectives on the above-mentioned project criteria, we propose:

1) To integrate multi-disciplinary knowledge, in the course of which a new subject — the BIM-based IVE collaborative design project – and its related teaching package will be offered to students and academic staff. Sessions will be designed to

provide students with an opportunity a) to clarify concepts with IVE and BIM, ideas and theories learnt from the theoretical background through collaborative group activities; b) to engage in internationalized interaction with teachers who help them to consolidate the learning experience gained through BIM-based IVE design and construction; and c) to provide constructive feedback to the class. Furthermore, we propose that these teaching materials can be applied to all AEC-related subjects requiring collaborative design and construction.

2) To assess the students' perceived change in knowledge of the above-mentioned subjects after participating in the sessions, by using focus-group surveys, questionnaires, and third-party evaluation.

3) To understand how students perceive the effectiveness and usefulness of interdisciplinary collaborative learning through the BIM-based immersive virtual environments and their overall learning experiences.

A framework for integrated platform for IVEs and BIM

These objectives are reached by means of cutting-edge technologies and project-based learning. First, the project provides students with an IVEs (e.g. Unity 3D, OpenGL, Unreal, Fuzor: KallocTec), into which 3D building models and Mechanical, Electrical and Plumbing (MEP) models can be imported and where the design can be modified in real time. In a virtual environment, the designers' goal is for the interface to be as transparent as possible so that it makes intuitive sense to prospective students. In the IVE, the interface should allow for direct manipulation of objects using hands, body movements, or by means of virtual tools that allow students to observe and interact within the IVE as naturally as they would interact with objects in the real world. Therefore, in this study, we will deploy some immersive input devices with haptic (sense-of-touch) feedback to users by using Oculus Touch and Leap motion sensors.

Second, BIM tools (e.g. Autodesk Revit architecture, Ecotect, eQuest, Sketchup) support students in planning and designing, and in visualizing their proposals. Currently, several universities around the world offer BIM courses in CM programs, while many others are in process of integrating BIM into their curricula. By offering internationalized curricula to local/global students, the course will inculcate a global perspective and better equip HK PolyU students to be global citizens through increasing their opportunities for international exchanges and internships.

Third, the projects involve multiple disciplines, with each student taking on a leading role, whether as contractor, architect, project manager, civil engineer, or Building Services engineer. Our aim is to gather representatives of different academic programs and industries to discuss learning approaches for incorporation at different levels of the university curriculum. Our efforts are intended to foster collaboration throughout the architecture, engineering, construction, owner and operator (AECOO) industry.

Lastly, project-centered activities encourage students to focus on real-world problems and challenges. In order to provide an integrated project perspective, this project will offer a series of lectures by faculty and industry experts from Architecture, Structural Engineering and Construction Management, providing a framework for understanding concepts, issues and state-of-the art practice in collaborative design processes and technologies. From these lectures and discussions, students will be enabled to reflect on their own experience with the design project so as to produce a revised process leading to improvements in future collaborative efforts.

Many first-class teaching programs around the world have already adopted virtual technology in their classrooms. With goals mainly relating to "collaboration in AEC design", Stanford's PBL lab is just one excellent example of the utilisation of virtual environments as a tool for collaboration between students and staff. The PBL lab's mission is "to educate the next generation workforce by engaging graduate and undergraduate students, faculty, and industry practitioners in multi-disciplinary, collaborative, geographically distributed PBL activities. PBL is a process of teaching and learning that focuses on problem based, project-centered activities that produce a product for a client. PBL will be based on re-engineering processes that bring people from multiple disciplines together." This is very close to our own goal. Stanford's teaching interests include: collaboration technologies, learning technologies, knowledge capture, sharing and re-use technologies, workspaces, learning and work processes that support collaborative, cross-disciplinary, geographically-distributed teamwork and learning. Elsewhere, Texas A&M University has developed multi-university collaboration program for virtual design and construction. The Texas course is designed and developed to promote discussion with respect to the roles played by owners, designers, builders, and suppliers. Specific attention is paid to BIM's role in various project platform delivery systems including DESIGN-BID-BUILD, DESIGN BUILD, CM AT RISK, and IPD. Similarly, the University of Massachusetts has introduced an education program utilising Computer-aided Design and parametric building modeller software (e.g. Graphisoft ArchiCAD, Bentley Architectural) and Knowledge of options to work collaboratively on Virtual Design and Construction (VDC) projects. From the trends in AEC education in universities, it is clear that project-based learning with advanced technology has become widespread, and this is a point that HK PolyU needs to address. Based on these methodologies, this study have conducted a preliminary experiment in HK PolyU, to investigate the feasibility of using a integrated platform of IVEs and BIM.

Case Study

To facilitate the IVE in BIM education for cultivating collaboration and effective interaction among stakeholders, this study incorporated two systems; Autodesk Revit (BIM software) and Fuzor (Virtual reality software). Since main contribution of this study is focused on the implementation of IVE based collaboration, in this chapter, the application of the Fuzor will be mainly presented hereinafter. A prerequisite for using Fuzor, a BIM model that contains issues to discuss among the stakeholders (e.g. Design review, quality check, etc.) should be required. One of the most common issues during design process is to reflect owner's opinion in the design. For example, designer and coordinator are required to show design alternatives on what exterior wall would be appropriate to the owner, and need to obtain the preferences of the owner to be reflected on the design of the exterior wall.

Design of a scenario

The scenario proposed in this study assumes that the material of the exterior walls was determined among the various design materials. Designer, constructor and structural engineer participated in this decision process, and the role of each of which was defined as follows (Figure 1):

1) Designer: Determine the best options out of three alternatives (Wallstone, concrete, curtain wall). Designer can develop and suggest his/her own criteria of the decision (e.g. aesthetics, life cycle analysis, etc.). Designer should consider whether the chosen alternative is defective in construction, and the final decision should be made after ensuring that the design is intact in terms of structural stability.

2) Constructor: Ensure that the alternatives selected by the designer are feasible for the actual construction on site. The student in charge of this role should agree with the designer based on various field situations (e.g., difficult to procure specific materials, need to use specific construction methods, etc.).

3) Structural engineer: The alternatives reviewed by the designer and contractor should be technically reviewed. For example, if the building has three or more floors, the designer and contractor should be informed of the assumptions that the durability and structural analysis of the building material must be performed separately or the structural analysis of the frame to be installed. If possible, a quantity surveyor can also be participated in the design review process to acquire the cost aspects of the

project.

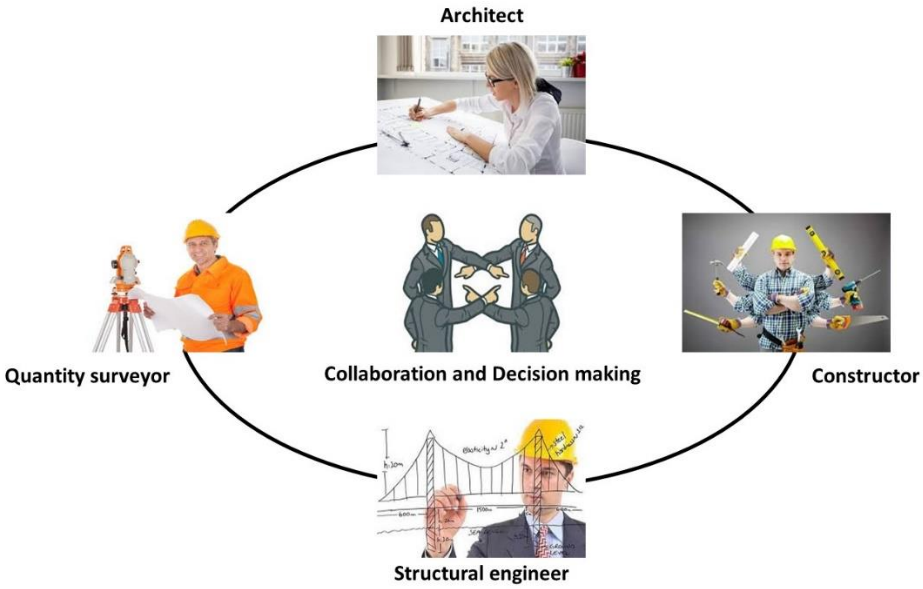

Figure 1. The (role playing) stakeholders for IVE based BIM collaboration in AEC projects

Through this process, stakeholders participating in the scenario were required to draw a single consistent conclusion and to assess the overall time it took to reach that consensus and how easy it was to make decisions, and how effectively students collaborated in their virtual environment. The following scene (figure 1 and 2) is depicting how the stakeholders are collaborate within the IVE. Figure 1 shows the hosts view of Fuzor, who can surveil them on what they are browsing so that the hosts can interact and communicate within the IVE. For example, if the designer pointed out a design element for a review, the constructor can easily notice the element through a guest cam, and they can discuss the arising issues on the fly. Figure 2 and 3 depicts a guided mode and text-based communication (As marked in Red) in case when the stakeholders have to share their field of view and have a documented report.

Figure 2. A collaboration scene among stakeholders; Constructor, Designer, Structural Engineer: Free roaming mode (Courtesy of Fuzor)

Figure 3. A collaboration scene among stakeholders; Constructor, Designer, Structural Engineer (Courtesy of Fuzor)

Discussions and Conclusion

With a basis in these overarching institutional strategic initiatives, this project will lend insight to teachers and students across departments, enabling them to cultivate an integrative learning culture, across institutions, optimizing the efficient and effective use of BIM-based immersive VR learning as a means of developing learning experiences and producing superior graduates equipped to meet the professional demands made by contemporary society. By means of the development of appropriate resources and their effective dissemination, it will be possible to develop a more desirable context to facilitate and enhance teaching and learning within HK PolyU and/or other institutions. Through these activities, students can develop multidisciplinary problem-solving abilities, effective communication and collaboration skills and lateral thinking, to become the next generation of AEC professionals. A multidisciplinary team from BSE (Building Services Engineering), BRE (Building and Real estate Engineering), LSGI (Land surveying and Geo-Informatics Engineering), CEE (Civil and Environmental Engineering) and the School of Design will develop, implement, test and evaluate innovative and collaborative learning through the BIM-based immersive virtual environment in AEC education so as to enhance collaborative, interdisciplinary, geographically-distributed teamwork and learning.

The impact of the project will be noticed primarily at subject level, where programme teams and individual teachers and students reap the benefits. Through the development and dissemination of resource materials and good practices, academic staff will be encouraged to enhance their students' learning by providing BIM-based Immersive VR design and construction that are the most likely to increase the demand for HK PolyU graduates in the employment market. Moreover, the opportunity to learn in a group during the lectures can provide more opportunities for interaction involving international students.

This collaborative and interactive educational framework and the deliverables of this study such as teaching and learning materials will be designed in such a way that any department or subject lecturer will be able to follow the step-by-step instructions to understand the key to interdisciplinary collaborative learning through the BIM-based Immersive virtual environment, and to design appropriate problems/cases, guide facilitators/educators to make optimum use of the teaching and learning experiences, and make appropriate assessment of learning outcomes. Additionally, it should be noted that the ideas in the presented study have been derived from departmental needs, thus guaranteeing that the outcome deliverables will be used by departmental members on a sustainable basis to create system-wide improvements in learning and teaching.

Acknowledgement

The authors would like to thank the Learning and Teaching Committee in the HK PolyU for providing funding support via Teaching Development Grant No. 1-49CV.

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