An Innovative Dynamic Gamificative BIM environment

Georgios Kapogiannis, Tianlun Yang, Ryan Jonathan And Craig Matthew Hancock, China

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SUMMARY

The need to improve the end user experience to interact with 3D models might contribute towards the delivery of more effective schematic and construction design drawings for refurbishment of existing buildings and improve end user experience. Past research shows the evolution of BIM in construction but so far there is not much research to show the interaction between a 3D model and the end user. Moving to industry 4.0 and Digital Twins is another evidence for improving the interactive experience between 3D models and end users. Therefore, this research shows how to gather data in existing buildings (houses – villa) using Lase Scanner and Photogrammetry, import and process these data to 3D Information Model (LOD 300), set the indoor position and thus to develop a dynamic interactive Gamificative BIM environment to enhance owners and end users experience through the use of HoloLens. Moreover, the indoor positioning system could help end user experience be improved due to the ability to walk through the digital model environment using HoloLens technology thus giving a more holistic understanding and more detailed information about the final digital product. This paper demonstrates the digital engineering strategy that was used. For this purpose, the team collaborated with an industrial partner to test and validate the impact of a dynamic interactive Gamificative BIM environment including its digital strategy. In fact, semi structured interviews with the design team was involved to test the hypothesis and observations to assess end user's reaction within this environment. Results show the efficiency of this dynamic environment in order to deliver both schematic and dynamic design closer to the needs of the client, as well as benefits to improve on time completion. This was achieved because of the improved interaction between the 3D Model and end user through the use of the HoloLens and Indoor Positioning in the premises of the Design Company. The integration of Revit to Unit and thus to the HoloLens Emulator has revealed many challenges. However, the team managed to develop an innovative approach for integrating the 3D Model to HoloLens in order to improve end user experience and thus to provide a comprehensive and continuous feedback by using (a)synchronous communication technologies. Benefits show also the added value to the business operation of the design studio due to early adoption and completion of the project. The company increased their capacity to support more projects and therefore to increase the profit.

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1. INTRODUCTION

The Building Information Modelling (BIM) paradigm on a global scale became an inventible approach to support the design, development and operation of smart cities. However, asset management is growing rapidly from a BIM perspective. According to ISO19650 asset modelling is one out of the core outputs of BIM that aims to improve the operational process and efficiency of use of an asset. As a result visualisation technologies have to be utilised as a tool for use by the client to aid in providing continuous feedback using interactive approaches.

Visualisation technologies are those technologies that use a diverse range of techniques for creating images, diagrams, or animations to communicate a message (Cleveland, 1993, Tufte, 1997). In fact, there are several types of visualizations that have been defined: scientific visualization, Information visualization, Visual Analytics. Ward et al. (2015) state that visualization is "the process of representing data, information, and knowledge in a visual form to support the tasks of exploration, confirmation, presentation, and understanding". Eastman (2008) provides a definition about the importance of geometrical representation of an asset in the provision of valued information of the asset. Examples of data visualisation are Charts, Tables, Graphs, Maps, Infographics, Dashboards. Data about the current geospatial information of a building can be provided/created using several techniques, the most popular of these techniques is laser scanning (Chen et al., 2019, Chen et al., 2018). Laser scanner technologies have advanced the capacity of data collection capabilities aiming to gather fast, accurate and non-intrusive as-built construction data that eliminates the need to return to the site for additional measurements. This data can be presented in real word coordinates. Yang et al. (2019) demonstrated theatrically how Integrating Indoor Positioning Techniques with Mobile Laser Scanner can create Indoor Laser Scanning Models.

GIS, VR, AR and 3D modelling for Survey techniques also contribute to the realistic visualization of construction sites and as-built buildings. However, during the design process the client usually reviews drawings in 2D during a face to face meeting. Though due to time constraints clients usually send a representative to comment and review without having the information first hand. This direct communication generates communication gaps that does not allow information flow to be consistent, transparent or to aid in increasing the level of trust among stakeholders.

Atkin (1989) considers intelligent buildings a "building that knows what is happening inside it and outside it and can decide the most effective way to create the right environment for users on time". Moreover, he takes on board definitions of input and output based on computational design principles. As a result, ,3D Geometrical Representation (Information Modelling) multiple design (Mixed Reality), data analytics (Big Data), algorithms (Optimisation) and automation (Artificial Intelligence) and simulation(Information Visualisation and Simulation) became part of the design process in architecture and over the years without though to incorporate real time human interaction approach.

Real time Human object interaction is something that is increasingly studied worldwide (for example at the National University of Singapore, University of Minnesota, Stanford University, Facebook AI Research Centre and Tsinghua University). Dawod and Hanna (2019) demonstrated BIM-assisted object recognition for the on-site autonomous robotic assembly of discrete structures. In 2011 there was a study about demonstrating a BIM-Game prototype that integrates BIM and gaming into architectural visualization. This aims to integrate architecture, engineering, computer science, visualization, and game development (Yan et al., 2011).

The question still remains how to improve the end user experience despite the fact gamification is in place. Moreover, Petridis et al. (2015) demonstrated how enterprises use digital games and gamification to improve many aspects of how businesses provide training to staff, operate, and communicate with consumers. Same year Wood demonstrated the successful impact serious games for energy social science research. But all these ideas and experiments were lacking on positioning system.

2. METHODOLOGY

In this paper a photorealistic environment was created by combining the learning approaches of situated cognition, discovery learning and constructivism (via continuous feedback), whilst engaging students in experiential learning using the theory of Active Collaborative Learning (ACL) (Sibley and Ostafichuk, 2015). This is achieved by processing data, information, knowledge & wisdom (DIKW) (Ackoff, 1989), and sharing both digital information and experiences with peers in a collaborative environment. Walker et al. (2020) presented the situation in which the use of VR in education is becoming increasingly common, but the explicit pedagogy utilized in these environments is rarely obvious or stated. However the researchers used a variety of tools and technologies to accommodate and improve end users experience.

The research is split into two case studies:

1. A case study within the Design phase of the refurbishment of an existing house. In this case study researchers beyond the experiment, run a qualitative study with open ended questions. Thematic method was used to analyse those data by using NVivo Software.

2. A case study during the Construction phase of the new Library at the University of Nottingham. For the second case study a quantitative study using survey data based on Survey Evaluation Module (SEM) of the Introduction to BIM module at The University of Nottingham Ningbo China. Descriptive statistics were used in order to measure mean value and understand the impact to students' performance and compare to last year's modules SEM survey.

The objective of Case study 1 is to improve the end user experience and the objective of Case Study 2 is to improve the teaching experience on BIM and Its Future - Digital Construction Innovation.

Figure 1 shows the process of various technologies and digital tools conducted during case study 1. Starting with 2D Drawings in AutoCAD and 3D modelling in Revit, and then using 3dMax and Unity to process the gamificative environment. The presented workflow allows the creation of several different presentation media such as images and videos for client discussion. These data could be transferred and access given directly to clients access to using a QR code from a terminal, phone or tablet. In this setup iCloud and Wechat were used as a common data environment.

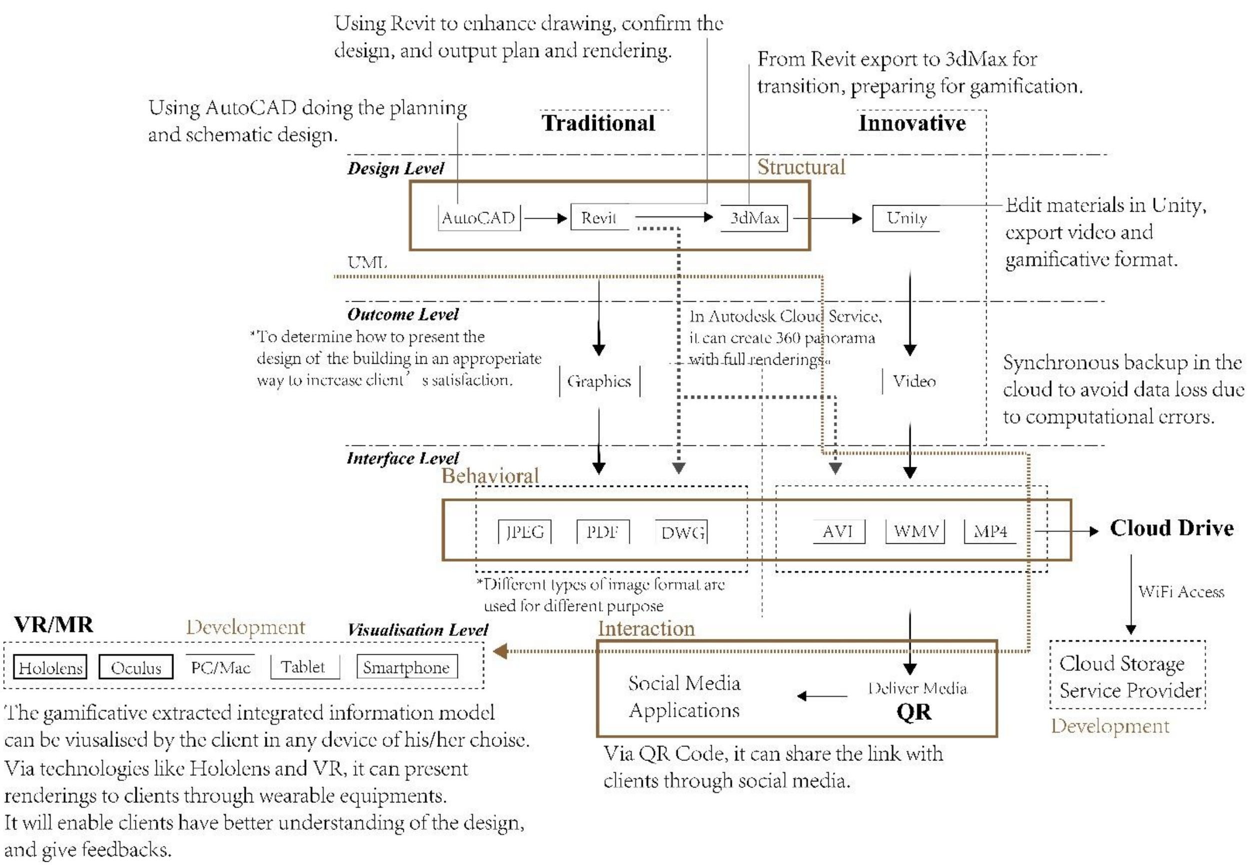


Figure 1 : Technology Process of Case Study 1

In order to make the idea more interoperable, interactive and innovative the integration of these technologies visualized through a mixed reality environment using the Microsoft Hololens platform. This unique approach allows the client to be within a dynamic and interactive environment in which the information can be visualized in 3D representation of the real world environment. The Hololens 3D environment allows the client to walk through the virtual representation of the building and allows the giving of feedback directly to the design and construction teams. ISO9650 was used for information management purposes.

Case Study 2

Researchers carried out an experiment during the workshop of the module "Introduction to BIM" so students can get a better understanding of how a construction site looks by eliminating health and safety challenges that accompany a physical site visit. The process workflow used during the module can be seen in figure 2.

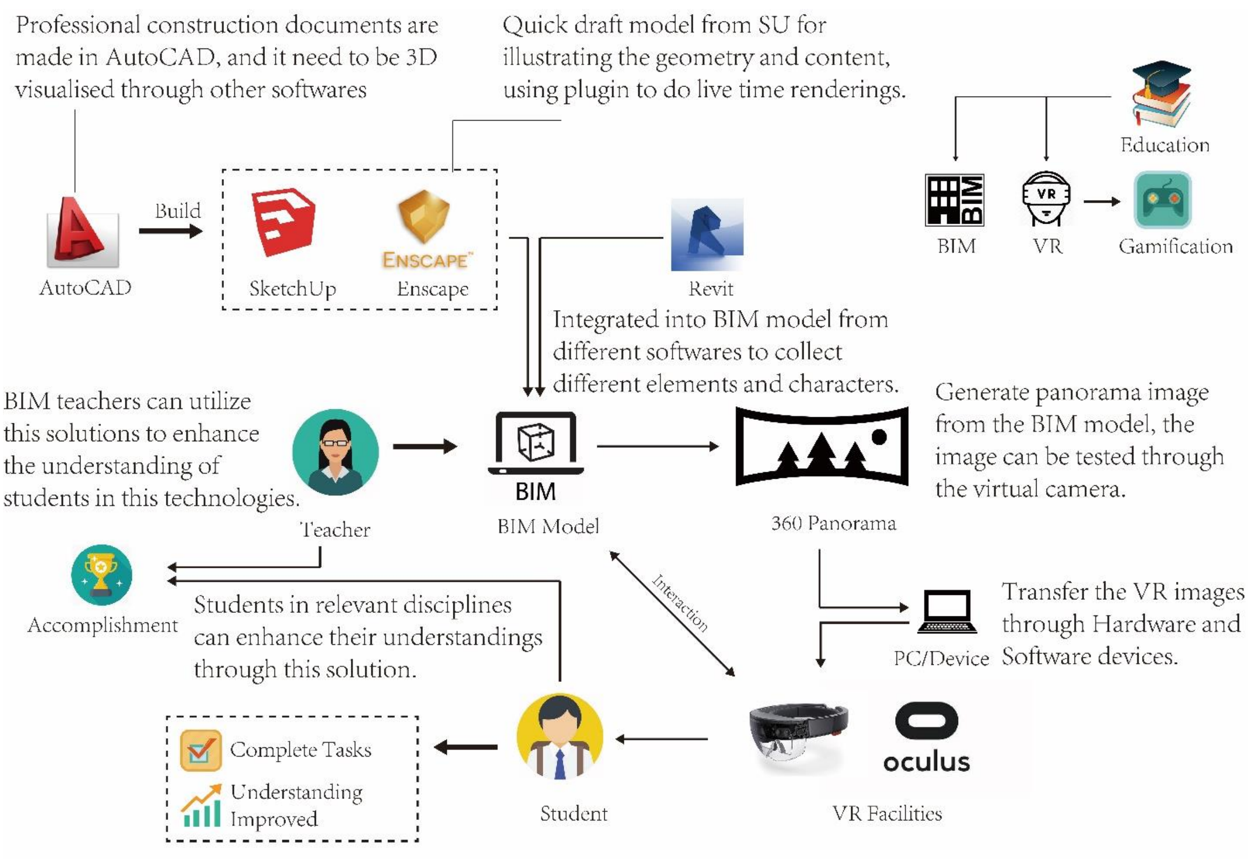


Figure 2 : Solution to Enhance BIM education

For case study 2 models are created based on AutoCAD 2D drawings (although they could also be created using as-built survey technologies), and then created 3D geometric model in SkechUp. There is a plugin in SkechUp called Enscape that can create a real-time rendering environment for better illustrating the design content. Various interaction between people and the model can be established by multiple visualisation tools.

3. DISCUSSION

From the validation and thematic analysis using NVivo software is case study 1 (based on the communication during a period of 1 month) some activities have been shown to have a positive effect. Activities that have been positively affected are: communication, discussion, suggestions and coordination. The experiment also raised a number of concerns in the following areas: Site Planning, House Programming, Site, Surroundings, Construction Issues, and MEP Systems. Through the common data environment the following data were shared using through the cloud: documents, diagrams, images, links.

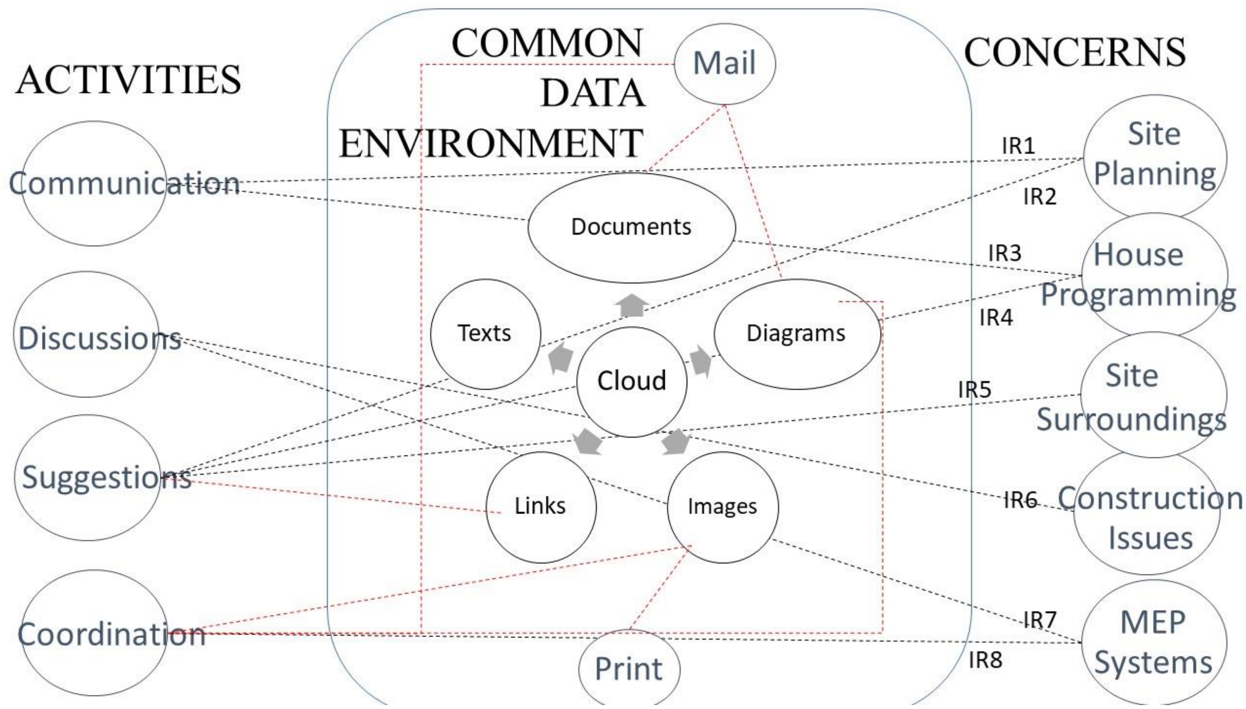


Figure 3 Qualitative - Thematic Analysis of the Validation

The experience using the actual 3D interactive gamificative model helped to enhance understanding about the final asset. Based on their experience and taking on board thematic analysis researchers found that the end user managed to improve in communication, discussion, suggestions and coordination which contributed to what Kapogiannis and Sherratt (2018) referred as to “collaborative culture”. According to the thematic analysis, interviewees were impressed as long as there knowledge and understanding about the 5 sub-themes: site planning, house programming, site surroundings, construction issues, and Mechanical Electrical and Plumbing systems was achieved was improved significantly. According to the data analysis these information were important due to increased costs that might affect the construction work and also this allowed the calculation of more accurate operational expenses. This follows the research by Eastman (2008) which refers to the importance of the end user/investor to have more and better quality information about assets over short, medium and long term. Lean construction in support of the BIM paradigm utilizing the integrating of multiple technologies clearly shows a way forward to enhance the Human Modelling Interaction (HMI), Improve End User Experience and Integrate VR and BIM with Mixed Reality. Moreover, interrelationships have been created from the written, oral and text communication, such as IR1: Communication and Site Planning IR2: Site Planning and Suggestions IR3: Communication and House Programming IR4: House Programming and Suggestions IR5: Site Surroundings and Suggestions IR6: Construction Issues and Discussions IR7: MEP Systems and discussions and IR7: MEP and Coordination. Though within the CDE despite the investor’s capacity to access directly to the context and content of the asset (model, modelling and management) still paradoxically there is the need for the end user to request email of documents and diagrams and printout of images; this is considered as a more conservative approach where in ergonomist as human factors that keep people reaction rather conservative (Charness and Bosman, 1992). Arguably this is not a problem but is a way to confirm and validate with the old traditional way the relevant ideas.

The fact though that Microsoft HoloLens developed a tool as untethered holographic computer aiming to empower end user experience through holographic technologies. As can be seen in figure 4 the HoloLens can use a variety human senses in order to enhance their virtual experience.

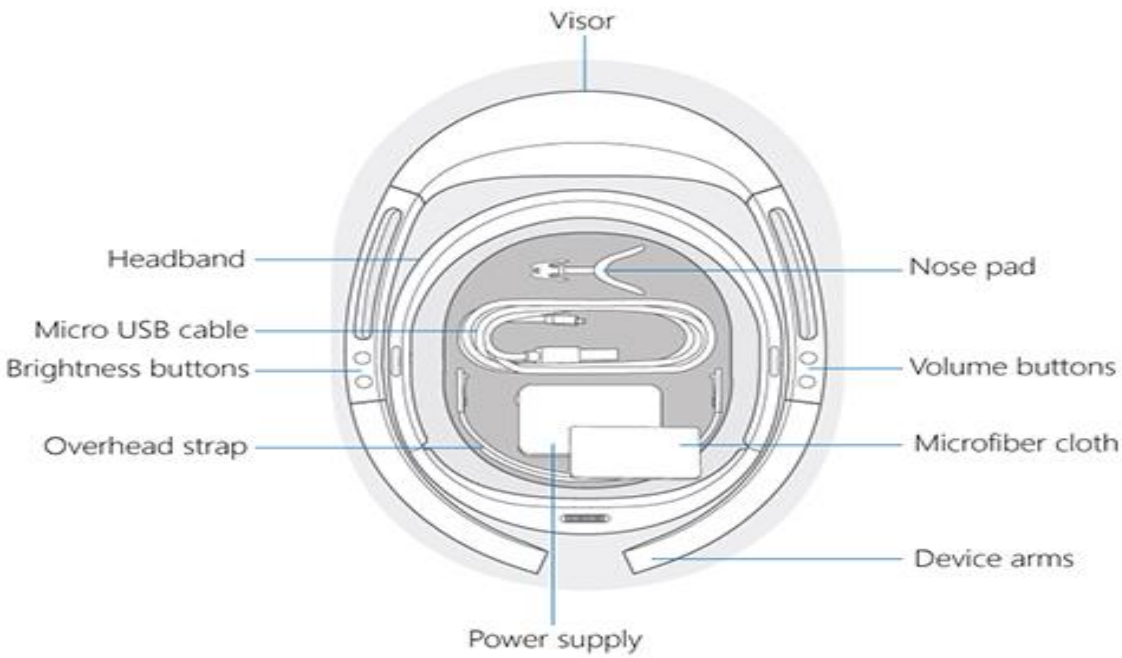


Figure 4 Diagram of the main features of the Microsoft Hololens.

This work demonstrates the means by which the client can visualize in a semi - static mode, through an AR/VR visualisation, a realistic representation of a building, in this case a house (see figure 5). Figure 5 shows some examples of what the client can see using the workflow and technology used in this project. Figure 5 also shows the different phases of the house considering time and location that was aligned using the HoloLens capacity to use indoor and outdoor location information.

For case study 2 students were benefitted from the technology in 3 major elements: a) advanced use of digital technologies in construction (digital construction), b) experience with HTC Vive - a VR environment (with cable and tracking sensors) and c) interaction with their peers to conduct their coursework (Figure 6).

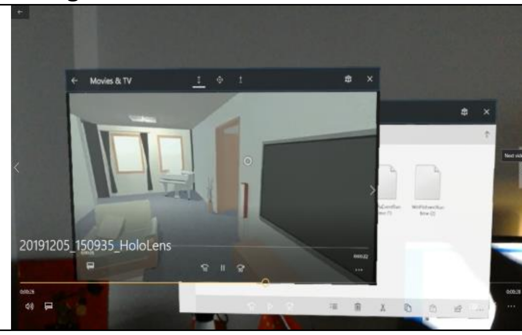
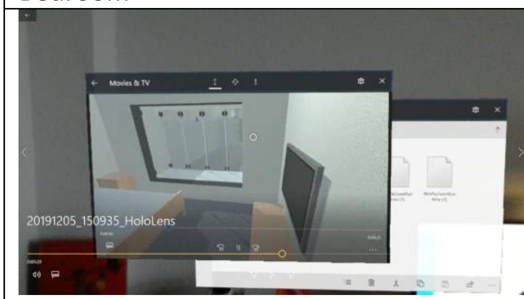
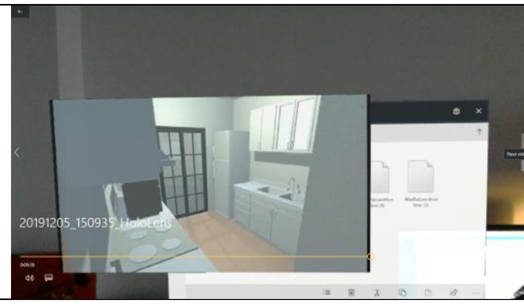
Main Entrance	Living Room
	
Bedroom	Kitchen
	
Stairs including shadow	Second Floor - Corridor

Figure 5 Examples of visualization using the Hololens

Figure 6 Interaction between Human and Virtual Information Model

In complimentary work carried out by Walker et al. (2020) the elements a and b are clearly demonstrated. Element c indeed contributed students to perform better in coursework submission December 2020 compare to December 2019 and in addition module feedback was improved by

3.7% compare to last year (2019 72.50% up to 76.2% in 2020). As a result an additional output of this research show that Architecture Intelligent Design based on Gamification impact on improving teaching and learning experience in Digital Construction – BIM.

4. CONCLUSION

In this research the team used a number of different technologies, methods and procedures to design and test a new workflow for architecture intelligent design based on gamification and how it could impact small projects in the construction industry and group teaching of digital construction at a university level. 3D Revit, HoloLens, VR, Unity, Gamefication, Laser Scanning/Photogrammetry as well as indoor positioning were among the technologies that were or can be used in order to understand the impact of this innovation. Results have shown enhancement of the teaching and learning experience in Digital Construction – BIM; enhancement of the Human Modelling Interaction (HMI), improvement of end users experience and technologically integration of VR and BIM with Mixed Reality in a gamificative environment as well as improvement in communications between stakeholders in small construction projects.

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BIOGRAPHICAL NOTES

Dr Georgios Kapogiannis is the Course Director of the MSc Program in Geospatial Engineering with BIM at the University of Nottingham Ningbo China where he is working as an Assistant Professor in BIM. Georgios is the National Winner of National Intelligent Construction Technology and Innovation Competition in China and has a number of publications, awards and other achievements in the domain of Digital Construction.

Mr Tianlun Yang is a winner of the National Competition National of Intelligent Construction Technology and Innovation Competition in China. Meanwhile, is doing his PhD in Digital Construction and Management at the University of Nottingham Ningbo China while is working as a GTA and Digital Architecture Designer at Zhejiang Jingwei Engineering Design Co. Ltd

Mr Ryan Jonathan is currently a PhD student at the university of Nottingham Ningbo China Driven by his curiosity and passion, Ryan tries to apply modern technology to solve current construction problems, such as monitoring sustainability. Ryan's interest in building design and construction industry guided him to achieve the first-class in Architecture during his undergraduate studies. Ryan also has a Masters in Geodesy and BIM.

Dr Craig Matthew Hancock is currently Head of Civil Engineering at the University of Nottingham Ningbo China campus. He obtained a degree in surveying and mapping science from Newcastle University (UK) and a Ph.D. in Space Geodesy also from Newcastle University (UK). His main research interests are GNSS Ionospheric error mitigation and Structural Monitoring.

CONTACTS

Dr Georgios Kapogiannis

University of Nottingham Ningbo China, 199 Taikang East Road, Ningbo 315100, Zhejiang, P. R. China

Email: Georgios.Kapogiannis@nottingham.edu.cn

Tianlun Yang

University of Nottingham Ningbo China, 199 Taikang East Road, Ningbo 315100, Zhejiang, P. R. China

Email: tianlun.yang@nottingham.edu.cn

Ryan Jonathan

University of Nottingham Ningbo China, 199 Taikang East Road, Ningbo 315100, Zhejiang, P. R. China

Email: ryan.jonathan@nottingham.edu.cn

Craig Matthew Hancock

University of Nottingham Ningbo China, 199 Taikang East Road, Ningbo 315100, Zhejiang, P. R. China

Email: Craig.hancock@nottingham.edu.cn