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Using Virtual Reality in Construction Education by Incorporating BIM

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ABSTRACT

Students in practical majors like construction management face several challenges in understanding theoretical concepts. Building Information Modeling (BIM) is a digital modeling tool used to present physical buildings and structures that can be used to develop an accurate representation of the work environment, including the performance limitations of structures and building elements. Construction Engineering Education and Training (CEET) can provide opportunities by incorporating BIM models to apply technical and theoretical insights and details to the intended construction activities. Virtual reality (VR) is a powerful visualization tool for the student to understand space and the performance of structural elements. The purpose of this analysis is to define an efficient educational tool by integrating VR application and BIM model information to develop 3D, 4D, and 5D simulations that dramatically improve students' preparation for a career in construction management. Implications for education system coordinators, researchers, and students are presented.

Keywords

Construction Engineering Education and Training (CEET), Virtual Reality (VR), Building Information Modeling (BIM), Information Technology

INTRODUCTION

Construction management is a highly desirable and practical major for contemporary students. Improving the educational experience across universities and colleges is a challenge for every instructional program. Enhancing the visualization aspect of training is seemingly straightforward. Superior educational outcomes could be achieved through improved student training, clear academic instructions, and protective and user-friendly equipment on location at a physical worksite. Implementation of each method requires a deep understanding of the relevant needs and challenges in the education system. Practical education in construction management and structural knowledge is crucial in enhancing the overall performance of future construction engineers and managers.

This study analyses technology solutions that can be integrated to ensure comprehensive training in the construction management discipline. The results can also be generalized to other fields that benefit from manipulating context-rich instructional elements. The complexity of construction education and visualization within practical courses are inadequate in a traditional lecture-based education system. Consequently, a critical challenge that must be addressed is how to support the creation and digital sharing of information presenting construction and structural knowledge through effective education, explanation, and incorporation (Getuli et al., 2020).

Tools are used to assist the system in implementing the goals and facilitating the information transformation (Getuli et al., 2019). Construction Engineering Education and Training (CEET) defines its usages, configuration approaches, dimensions, and the building elements under construction. The effectiveness of CEET strongly relies on the two critical information technology areas. Virtual Reality (VR) is a helpful and powerful tool in engineering, architecture, and construction (Alizadehsalehi et al., 2019). Building Information Modeling (BIM) is a technology and robust database in the building projects for the Architecture, Engineering, and Construction (AEC) Industry that can facilitate the design and construction operation of the project (Wong et al., 2011). Clarifying and creating a tangible environment based on the practical visualization workflow would result in a more effective education. Providing and using relevant, effective content for each material and method was the challenge of the previous research. This content should demonstrate to the students the components of the construction project and the expectations they would realistically observe on site. The effectiveness of the technology in an educational system should be studied by analyzing the applicable learning goals. The usability of the environment or having a tangible environment could be considered in this analysis (Lucas, 2018). Therefore, it is necessary to employ sound theoretical foundations in order to facilitate understanding between all educational partners, including

students, information suppliers, and professors. The necessary expertise could be produced by developing 3D models of the structure, converting this experiential asset to the integrated development software that supports the VR applications. This would allow students to experience an introduction as they navigate the virtual environment with simulated facilities. This quick education gives them an opportunity to feel the actual situation by interacting with the virtual projects, including the structures, shapes of components, the type of joints, finished material surfaces, elements' behaviors after loadings, the systematic integration of components, and finalizing the projects after each assembly (Kavanagh et al., 2017). The purpose of CEET is to provide an environment to educate complex skills. This study researched innovative connections using advanced information technologies, Building Information Modeling (BIM), and Virtual Reality (VR), which will be used as an educational tool in CEET. The integrated tools can simulate elements demonstrating this information in 3D and 4D dimensional building models (special and temporal dimensions). Advanced BIM simulations (e.g. BIMEX) include cost estimations (i.e. 5D). This approach will improve complex instruction and effective communication in higher education. Based on this background, we propose the following for future research:

Proposition 1: Combining BIM and VR lead to more effective CEET.

Proposition 2: Combining BIM and VR in CEET reduces miscommunication.

The Evolution of BIM and VR in CEET

One of the critical elements which affects the efficiency of construction management education is the availability of the site workspace, along with essential elements that change over the lifecycle of a project (Getuli et al., 2020). BIM (modeling) can connect with VR technology to satisfy this training requirement in simulating construction sites. However, the current paucity of content (e.g. images, dimensions, and behaviors) for educational purposes is a significant obstacle that needs to change rapidly. Students are generally receptive to this approach; however, without a collated library of content, the technology's use will remain limited (Getuli et al., 2018). In response, BIM can provide content to incorporate information with VR to implement an innovative technology platform in CEET.

Substantial time is required to learn and develop these technologies with specialized hardware or software and to create practical exercises for effective learning. Many instructors may find this process too time-consuming and, therefore, of questionable value. In addition, these technologies may not be attractive to instructors that are not familiar with the technology (Seppänen et al., 2010). However, the ease of use associated with BIM would likely improve the experience for the instructors and reduce their level of resistance. The low reliability commonly related to these technologies in the past was primarily due to a lack of understanding of specialized workspace technologies and databases. These challenges have been ameliorated by advanced technologies. The present research is supported by technology findings in two significant areas, VR and BIM (Getuli et al., 2020; Seppänen et al., 2010). Additionally, there are no differences between the younger and older adults in their ability to benefit from VR training (Dobrowolski et al., 2021).

In the construction management field, BIM is often used in the pre-construction and design phases of the project. The increased use of digital models at all stages in CEET could improve student understanding and increase BIM use as an information database (Getuli et al., 2019; Isaac et al., 2017; Su et al., 2018). Two central problems deserve further investigation:

a) How to seamlessly connect BIM to VR. Previous research presented a system that allows immersive visualization using the Oculus Rift HMD (Head Mounted Display). This integration can make the use of VR more accessible. Instead of focusing on the architectural part of the BIM, in this research, we use this concept in the structural part of the BIM to integrate with VR (Getuli et al., 2020).

b) The need for BIM tracking in CEET regarding the building component. Potentially adverse factors are classified into different categories: technology, cost, management, personnel, and legal. We seek to classify BIM outputs into relatable parts and assign each part to one aspect of CEET. For instance, Building Codes and Inspection, Structural Engineering, and Construction Engineering Materials are the individual areas considered in this study (Kavanagh et al., 2017).

DEVELOPING AN APPLICATION TO VISUALIZE BIM MODEL OVER VR

There are some restrictions on implementing this technical solution (Alizadehsalehi et al., 2020, 2021; Tan et al., 2021). Visualizing appropriate data using VR in a BIM model can produce an actual building construction project in different phases (Alizadehsalehi et al., 2021). BIM and VR need to work in a comprehensive process. VR workflow must first be clearly defined. Commercial software can perform the conversion of information to VR. Requirements include

headsets and sensors to track location and movement and stereo headphones to produce surround sound (Alizadehsalehi et al., 2021).

Alizadehsalehi et al. (2019) defined a technique called ICAM for the structured analysis and design of systems used for function modeling. ICAM is an integrated computer-aided manufacturing method (Alizadehsalehi et al., 2019). The authors describe and illustrate the BIM-into-VR workflow to illustrate the processes required in this type of model. The model designed by the authors of this manuscript is based on the results of previous publications (Alizadehsalehi et al., 2020; Du et al., 2018), industry applications, and personal experiences. The stages of generating a 3D or 4D model using VR are used for education and visualization purposes in the CEET. Identifying the educational goals for each course should be completed before preparing the BIM model. Figure 1 shows a schematic view of the steps needed to create a model in BIM using VR (Alizadehsalehi et al., 2021).

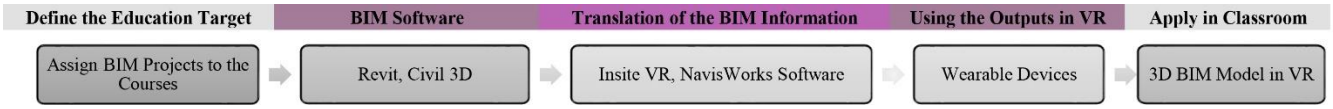

Figure 1. Schematic View of Transferring Education Target to 3D, 4D Simulation by Using BIM and VR

THE INTEGRATION OF INFORMATION TECHNOLOGIES FROM BIM AND VR

Information systems play a critical role in university education programs, from learning management systems to statistical packages, from visualization tools to programming. On the one hand, numerous VR applications can be utilized in the education and training spaces. Several researchers have conducted theoretical studies on the importance of using VR in programs related to CEET. VR can create a unique and practical training space that does not exist in fundamental academic areas, especially in areas that involve high touch and hard-to-solve problems (Li, et al., 2018; Liu et al., 2015). Jason Lucas researched student perceptions after allowing them to experience a virtual environment utilizing Samsung Gear VR headsets and Samsung S7 devices (Lucas, 2018). He found that it was a very interactive method for participants to search and visualize concepts and material learned in the classroom. However, findings are influenced by how long students use the technology, revealing that extended use can face several issues such as availability, expense, and lack of content for the materials in each relative course. VR can empower users to examine alternative solutions to problems by comprehensively considering learning targets (Baxter and Hainey, 2019). VR technology is an effective way to decrease the cost of real-world projects. Wang et al. (2014) illustrated that both time- and cost-savings are possible by using VR technologies. By decreasing labor and time, cost efficiencies are realized through the elimination of defects and subsequent construction rework (Wang et al., 2014). In addition, Le et al. stated that using VR technologies for worker training could reduce safety issues in the construction project and decrease the overall cost of the construction projects (Le et al. 2015).

On the other hand, some BIM-based research studies focused on the BIM transition in education. BIM transition is one of the essential users of information technology in engineering departments, focusing on the importance of BIM-based education in CEET-related courses and abilities (c.f. Alizadehsalehi et al., 2021; Azhar, et al., 2010; Clevenger et al., 2010; Getuli et al., 2020; Guo et al., 2017; Khosrowshahi and Arayici, 2012; Wong et al., 2011). Graduates will utilize the technology in real-world projects through this understanding and visual adaptation. Construction management students must understand the behavior of the features and how they are joined together.

UTILIZING BIM WITH CONSTRUCTION MANAGEMENT STUDENTS

The process starts with creating BIM-based models of the building for the specific project. The model includes all the building components, elements, and project phases contained in the construction procedures. After that, the building information is organized in terms of educational requirements. Possible clashes or issues are later analyzed based on the workspace experiences to select the appropriate model for each subject of education. As shown in Figure 1, an initial education configuration should be modeled without considering site boundary conditions (Getuli et al., 2020). Finally, leveraging tacit knowledge using VR activity simulation generates a valuable workspace configuration. The integrated BIM and Site Information Model creates an authoring platform that will export 3D building behaviors for the intended purpose.

There are structural, plumbing, mechanical, and electrical modules in BIM to illustrate the various details of construction possibilities (Nateghi and Torbat, 2015). Integrating structural and architectural understanding will generate a higher probability of academic and career success while providing high-quality engineering services.

Implementation of VR-BIM Simulation in CEET

A 3D model is developed to create an immersive and engaging space to train students using VR to simulate construction operations. The next step is to identify critical activities and assign each manipulation to the intended section of the BIM model.

It includes tasks and features assigned to specific parts of a multi-dimensional information model in BIM. The experience and knowledge of experts and managers are elicited to organize the suitable workspaces to represent every detail in information modeling. The data from the different dimensions of the BIM model are intended to be used in other courses in CEET, leveraging the development efforts throughout the curriculum.

Real validation in the education system can be defined as the final implementation process. Execution of workspace activities and the behavior of structural elements is proof of successful VR-BIM integration.

IMPLICATIONS FOR INFORMATION SYSTEMS

This paper has introduced an impactful use of technology in the construction management education space. As discussed above, there remains hesitation on the part of some instructors to adopt these innovative solutions, even though the results are unmistakably positive for students. Information systems (IS) adoption continues to be an important consideration in higher education, as well as in industry. As a contribution to promoting these solutions, future IS research should investigate the barriers that currently impede adoption, such as awareness, intimidation, perceived steep learning curve, technical support, and others (e.g. Buche, et al., 2012; Gibson, et al., 2008; Marks and Thomas, 2022). Increased measurable knowledge generation is another potential focus for IS researchers. Reporting experiential results of superior expertise will likely encourage more instructors to delve into this robust, immersive educational format. We anticipate that IS and technical support will be key to future dissemination.

CONCLUSION

Building Information Modeling (BIM), as an information system in construction management education, creates building information databases for use by instructors and students. VR has been adopted to address learning challenges and assist learners in continuously improving training skills in the construction management discipline. Increasing efficiency by utilizing information system tools like BIM and VR would play a critical role in instilling theoretical knowledge and simulating the actual environment of the workspaces. BIM delivers a multi-dimensional model, enabling students to benefit from a deeper understanding and conceptualization of building elements' behaviors and construction process relationships. VR-supported training can be an excellent choice to generate 3D simulations for the students to learn concisely with as many details as possible in a variety of academic disciplines. BIM and VR integration as a combined simulation platform provides effective training that helps to overcome common educational challenges. With training and experience, instructors might become passionate about using this information technology tool. Graduates will then apply their knowledge in the workplace to address clashes and solve the actual issues they encounter. As BIM increases availability of models and images used to populate repositories, this technique will become the gold standard for construction management education.

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