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The Implementation of Virtual Reality-Building Information Modelling in Botswana Higher Education AEC Programmes

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Abstract— *Botswana as a developing country will see an immense growth in the construction industry. A reflection on the construction history of Botswana and a peek into the future Botswana's construction industry illustrates a country with a sure growth in the construction industry. Therefore this paper will discuss why and how incorporating Building Information Modeling (BIM) and Virtual Reality (VR) Technologies into higher education teaching practices can ease the industry towards transitions in the technology era. As the construction industry transitions, adequately qualified students and specialists will become crucial for the Architectural, Engineering and Construction (AEC) industry. The adoptation and adaptation of Building Information Modeling (BIM) and Virtual Reality (VR) across the world by governments and private industries has made it mandatory to embrace construction technologies in various forms. The introduction of VR and BIM would transform the AEC industry. The use of three-dimensional (3-D) immersive learning can enrich student's ability to identify various building principles, as well as increase engagement and retention which can make the learning experience meaningful. This paper advocates for implementing VR-BIM into the AEC undergraduate program.*

The paper carries out a methodology for implementing the VR-BIM. By reviewing previous literature, making an in-depth analysis of the program and accreditation requirements. This paper illustrates how VR-BIM can be implemented in the curriculum into existing course model. Potential challenges to the VR-BIM implementation are identified and some solutions proposed. From this perspective lab classroom layout suitable for the application is designed and adjusted to various layouts to accommodate different teaching practices, learning styles and objectives. Comparisons between head-mounted displays (HMD) are considered and suitable equipment proposed.

Keywords—BIM;VR; Architectural Engineering and Construction; Higher Education Curriculumn

I. INTRODUCTION

BIM adoption is spreading like a wildfire across the engineering, and constructions industry (Hong et al 2020). Currently to accommodate the need for Building Information Model (BIM) and Virtual Reality (VR) experts the industry outsources expertise, however this is not a sustainable solution longterm [1].As the industry embraces and adopts BIM and VR a demand for professionals competent in the use of BIM and VR will increase [2]. As the industry transitions a more sustainable solution would be the production of BIM and VR qualified graduates ([3], [4]. BIM-VR qualified are a significant need of the future Architectural Engineering and Construction (AEC) industry workforce [5]–[7]. AEC graduates are unprepared for a digital future and research has suggested AEC educators embrace digital technologies to transform the industry [8]–[10] .

A. What is BIM

The National BIM Standard, defined BIM as "a digital representation of physical and functional characteristics of a facility, forming a reliable basis for decisions during its life cycle from inception onward"[11]. [12] define BIM as "a modeling technology and associated set of processes to produce, communicate, and analyze building models." BIM Models are made of smart objects representative a physical element such as doors and columns that hold a set of data. It can virtually build a structure before physically constructing it, allowing the project participants to explore and analyze a project digitally and make changes. Practicing BIM in the Industry has optimized construction, led most contractors' adoption of it in various parts of the world, when compared to architects and engineers (McGraw-Hill, 2012). The outcomes of BIM definitions enlightened AEC users to embrace BIM in construction industry. VR has been implemented into the BIM curriculum as a visualization technology tool which offers interaction of virtual models in virtual environments. It can be applied in teaching architectural visualizations for learners to appreciate the final model. In structural engineering it can be

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used to visualize to optimize the structural design of a building or for error checking and collision detection. It is evident that immersive learning experiences are possible Virtual Reality in the AEC curriculum (Bouska & Schneiderova Heralova, 2019). Previous studies in education have found that VR increases student engagement, increases enjoyment, mastery and promotes immersive learning experiences through simulation (Mystakidis, 2022; Suleman, 2019; Edwards, 2018). VR creates replicas of the real environment when well executed it can be an effective tool for higher education (Krajcovic et al. 2022). Instead of using the traditional paper data and 2D layouts learning experiences can be more immersive when students walk through an AEC environment virtually. And the more complex and actual the virtual replica students can see problems and even design accurate or replicate accurate real world scenarios.

The COVID pandemic helped many AEC, universities and their stakeholders to realize and utilize BIM and VR technologies. BIM alone cannot accomplish all needs required in construction industries, the virtual reality (VR) coupled with BIM can improve the accuracy of designs, speed up the construction process, and reduce costs by enhancing efficiency and collaboration of BIM-VR. It brought attention to BIM-VR revolutionizing the construction industry at large. BIM-VR is an interactive multimedia technology that enables users to connect with digital objects, offering users a simulated physical presence in an enhanced virtual world (Biocca & Levy, 1995). Virtual Reality (VR) idea was to simulate BIM and able to define VR in conjunction to AEC industry. Dioniso et al. 2013 defined VR as computer-generated simulations of three-dimensional objects that look real and need physical user interaction. VR technology has a wide range of applications that can help a project with accelerated site training and protection, design progress, and coordination with all parties involved, and lower project costs (Behzadi, 2016). Type of VR, Immersive VR is one of the useful one because it immerses the user into an environment and gives them a sense of presence in a location where they are not physically present.

Various type of VR is used in different important sections of AEC projects, therefore the combination of BIM- VR are the future of the building industry. In the modern construction process, BIM and VR technologies are used to perform worker safety preparation, defect management, quality management, project scheduling, knowledge collection, safety management, logistics management, and project progress assessment (Ahmed, et al., 2017). Adding the virtual interface technologies to BIM will continue to revolutionize the instructional methods used in construction education and enhance students' learning experience (Messner & Horman, 2003). The 3D immersive experience can be a valuable resource for strengthening students' ability to build their sense of space (Paes, et al., 2017).

While BIM has developed into a trending innovative technology, its applications and benefits in the AEC industry have not been maximized primarily due to a lack of trained BIM professionals (Gu & London, 2010; Lee & Hollar, 2013). This demand is followed by a necessity to implement BIM in AEC education. Introducing BIM in learning can indicate the latent potential of BIM in developing learning capacity in a collaborative construction industry. Therefore, many institutions must adjust their program curricula to integrate BIM (Chen & Gehrig, 2011). Several studies have considered BIM in higher education from international perspectives (Babatunde Solomon, 2018; Kim et al. 2017; Ozorhon & Karahan,2017) In Botswana however this remains untouched territory and research has not been adequately discussed the possibility implementing a BIM curriculum in higher education. This gap remains in the prevailing body of knowledge which is the motivation for this paper. BIM-VR technologies should not be treated as an optional division but rather a principal element of AEC curriculum (McPhee, 2016). BIM-VR technologies must be adopted a core and consistent pedagogical practice (Gelic & McLeod 2018).

BIM-VR research in Botswana is limited when compared with the developed nations, so this project contributes to the body of local knowledge. This work will therefore be beneficial to the various industry stakeholders in the private and public sectors such as Special Economic Zones Authority (SEZA), Morupule Coal Mine, DEBSWANA, Association of Consulting Engineers Botswana (ACEB), Botswana Engineer Registration Botswana Engineer Registration Board (B-ERB), Botswana Institute of Engineers (BIE), Botswana Innovation Hub (BIH), Ministry of Infrastructure of and Housing Development (MIHD), and Ministry of Finance and Economic Development (MFED). The focal point of the research is to suggest possible strategies that may be initiated by the Botswana educational administration, government and other regulatory agencies to promote BIM-VR adoption. The project will therefore help public officials and decision makers influence future policy making for supporting BIM digital technology usage in the Botswana architecture engineering and construction industry as well as educational institutions.

A. Global perspectives on BIM digital technologies

BIM digital technologies is an innovation that has spread like a wildfire across the globe, due centralized model which requires all engineers work on the same model, as compared to old times today's models are bringing the entire team in one centralized model which fosters collaboration and distance is no longer a barrier as everything can be done remotely BIM is on the rise worldwide. It is currently required in all governmental projects in the USA Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth (2017), and gaining wide industry awareness and adoption in European Union Eadie, Browne, Odeyinka, McKeown,&McNiff. (2013) Similarly, BIM implementation is moving rapidly in Hong Kong and Singapore as clients have started to realize its various benefits [13], [14] While BIM adoption is promising in the above countries, it is considered to be relatively lukewarm in developing regions Saka & Chan (2019).

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B. SADC perspectives on BIM digital technologies

In the SADC region BIM use remains relatively low. In his study Saka & Chan (2019) found that BIM is still in its germination stage in southern Africa and few studies have considered BIM development in the engineering and construction industry. BIM was only introduced in South Africa around 2004 (Kotze, 2013). In comparison to the aforementioned developed countries, South Africa is less mature in terms of exposure and usage of BIM. Examples of where BIM has been used are for the construction of the Nelson Mandela Bay and Mbombela stadiums for the 2010 FIFA World Cup. Although South Africa is starting to experience an increased uptake in BIM (Kotze, 2013), However South Africa has taken steps towards the implementation of BIM digital technologies. Mutale, Danstan, Tembo, Matipa & N'gandu (2014) in their paper titled Building Information Modelling: an assessment of its viability in cost management in the Zambian construction industry found that limited knowledge regarding BIM resulted in limited use in the Zambian construction industry Zavirima (2022). In Tanzania studies reflected the low awareness and knowledge of BIM led to slow adoption of BIM digital technologies Ally & Makenya (2018).

C. BIM and VR in Higher Education

Academia and the AEC industry are aware of the growing need for BIM-VR ready graduates (Hosseini et al. 2018; Hosseini et al. 2016). BIM-VR cannot simply be a one size fits all. A consensus must be reached on the requirements and curriculum direction (Wu et al. 2015) Effective BIM-VR curriculum must be tailor designed to suit culture and industry-oriented curricular (Best & Langston, 2005). There needs to be a connection between curricula and the industry, graduates must be fully prepared to competently perform BIM and VR related tasks. Another barrier is lack of limited availability of BIM educators and expert support (Mills et al. 2013) BIM and VR is relatively new and few educators are trained to teach BIM and VR content (Hon et al. 2015).

II. Conclusion

The necessity of BIM-VR technology advancement in Botswana's architecture engineering and construction industry, for higher education is a relevant necessity, and a graduate is likely to be absorbed by highly rated companies if BIM digital technologies. is part of their profile, they even become internationally competitive. BIM-VR digital technologies encourages sustainable economic development, environment maintenance, reducing inequality and collaboration in goal achievement. Moreover, should Botswana adopt BIM-VR digital technologies., the nation will be recognized as having standards and this will be a fulfilment of some international standards and agreements. BIM-VR digital technologies implementation has a potential in Botswana as informed by patterns in the developing world and more recently in neighboring South Africa.

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