Piloting Mobile Mixed Reality to Enhance Building Information Modelling Delivery in Construction Education

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With new building information modelling (BIM) workflows becoming required within the architecture, engineering and construction industry, more research is required to understand the best pedagogical delivery methods of this new spatial technology workflow. Mixed reality (MR) and mobile visualisation methods are identified as important technology drivers for rethinking higher education, practice driving learner engagement and spatial information delivery. This paper outlines qualitative results derived through thematic analysis of learner observation and reflections from a technology-enhanced lecture, and hands-on workshop focused on MR-BIM innovation within the construction industry. Forty-five (45) participants from a postgraduate construction course at an Australian University participated in answering the research question: "How do learners perceive the interactive visualisation mode of a presentation delivered through MR-BIM and mobile pedagogy?". The results of the analysis identified two general themes (learning and technology) and five sub-themes (learning engagement, learning experience, technology experience, technology readiness and technology future). Students felt engaged during the session with observation supporting the reflective analysis evidenced by learners asking questions, commenting on technology possibilities and sharing of their experiences between peers, lecturers and social networks. More work is required on the delivery method, with only one-third of the reflections discussing the learning.

Keywords: virtual reality, augmented reality, mixed reality, mobile learning, BIM, AEC education

Background

Architecture, Engineering and Construction (AEC) projects are growing in scale and becoming highly complex; thus, the massive information and data in a project can be overwhelming if not managed properly. Compounding this are the governance requirements within the AEC industry for compliant buildings and optimised process and communication workflows requiring new and innovative technologies (Chan, Ma, Yi, Zhou & Xiong, 2018). With ever-increasing problem complexity and governance requirements within AEC, a disruptive technology, Building Information Modelling (BIM) has been identified as a tool to improve the efficiency of the management process, promote coordination, and collaboration among project participants enhancing project interoperability. BIM is an information and communication technology (ICT) that integrates multidisciplinary collaboration throughout the project lifecycle with many countries implementing measures to implement BIM into their public projects. Given this, there has been a rapid shift in the AEC education practice to integrate BIM into course content, which has led to difficulties in integration (Puolitaival & Forsythe, 2016).

This challenge is compounded with the learner's expectation that they be engaged by their environment, with participatory, interactive, sensory-rich, experimental activities (either physical or virtual) (Jones, Ramanau, Cross & Healing, 2010) and higher expectations for input opportunities with individualised resources for productive and effective student outcomes (Sadler-Smith & Smith, 2004). Learners are characterised as more oriented to visual media than previous generations preferring to learn visually by doing rather than by listening or reading. This has resulted in a shift away from traditional face-to-face, didactic lectures and tutorials to self-direction, collaborative peer learning and technology-enhanced teaching and learning through multiple delivery modes and coding methods (Clark & Mayer, 2016). The 2019 Educause Higher Education Horizon Report (Alexander et al., 2019) captures this as a *Wicked* challenge impeding higher education, requiring a rethinking of the practice of teaching.

New mixed reality (MR) and mobile technologies are identified as important technologies and drivers for rethinking higher education practice and learner engagement (Cochrane, Smart & Narayan, 2018). Specifically, new mobile MR (MMR) visualisation is being explored within AEC design workflows (Birt & Cowling, 2018; Birt, Manyuru & Nelson, 2017) with positive usability results. However, currently, there is limited research into the effect that MMR workflows have within BIM education and how this can enhance and optimise the AEC industry. More detailed research is required in the design methods, simulation and communication, especially as it relates to BIM in construction education and integration for learners (Puolitaival & Forsythe, 2016).

This paper outlines the qualitative results of a pilot project to integrate MR-BIM and mobile delivery into a postgraduate construction subject using thematic analysis of the learner's reflective comments and observation on the technology-enhanced delivery method answering the research question: "How do learners perceive the interactive visualisation mode of presentation delivered through mixed reality building information modelling and mobile pedagogy?". Specifically, the learners where given a lecture on innovation within the construction industry focusing on the applied use of virtual reality (VR), augmented reality (AR) and artificial intelligence (AI) delivered using innovative MR technology and BIM models and then split into small learning groups for hands-on experiential learning with mobile VR and AR technology.

Methodology

The specific lesson was run in the first trimester of 2019 at an Australian University and involved 45 postgraduate participants from the construction course SDCM73-100 Professional Portfolio. The subject uses situated learning and encourages students to develop their professional skills in a real-world environment by combing self-analysis and reflective learning skills with professional methodologies, to expand analytic and strategic thinking capabilities as it relates to the construction profession. The students were given a 60-minute lecture (see Figure 1) on the impact of AI, VR and AR technology within the construction industry with a demonstration of HTC VIVE and HoloLens technology as it applies to the construction industry and BIM visualisation. Students were then asked to complete two hands-on learning tasks using mobile AR (see Figure 2) and mobile VR (see Figure 3) by exploring BIM models and real-world locations enhanced with the technology.

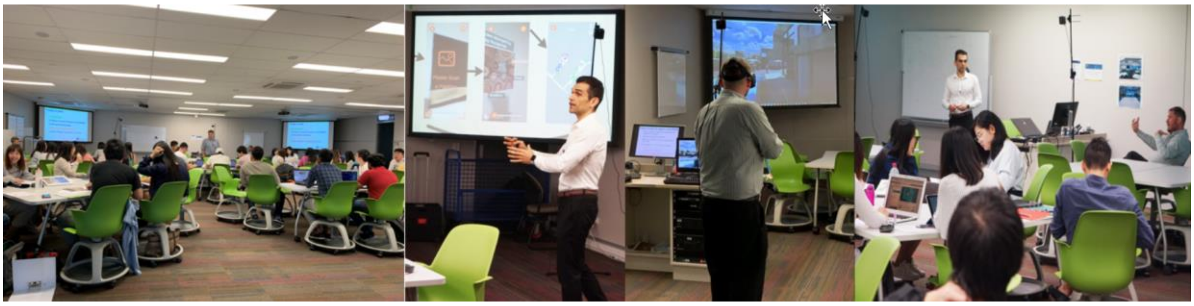

Figure 1: Future of work and impact of AI/VR/AR technology within the construction industry lecture

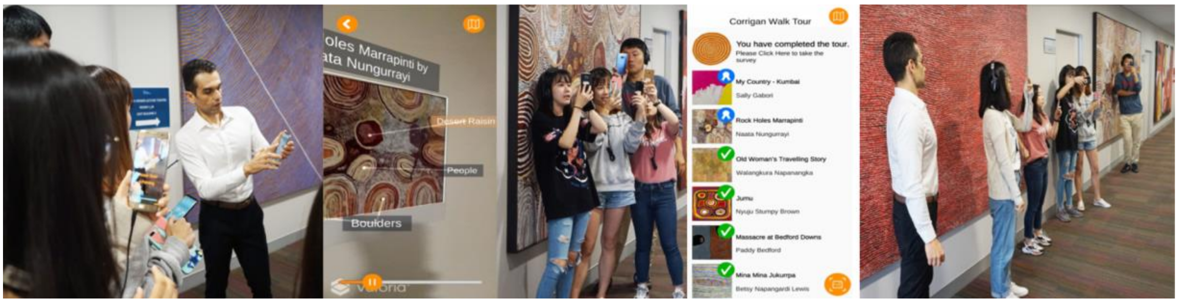

Figure 2: Augmenting the built environment place hands-on with mobile AR technology

Figure 3: Communicating the virtual built environment hands-on with mobile VR technology

For the mobile AR technology hands-on, we used an in-development, mobile app called *Corrigan Walk Tour* (Vasilevski & Birt, 2019). The app was built as an AR guide for the indigenous artworks collection at the learner's institution. This app was used as an example AR application for the students to understand the applied nature of AR within a built environment place. The students started the app with 5 minutes of onboarding, including detailed explanations on navigation, app objectives, and how to optimally use the app. We did not talk anything about the artworks or the indigenous culture, hence enabling the students to discover and learn this information by themselves individually through the app. The students were provided with Android Samsung Galaxy devices to minimise variation and headphones to prevent sound pollution and interference with any activities at the place. The tour was conducted to enhance the learners understanding beyond only the specifics of BIM construction data management to include factors around coordination, communication, design methods and simulation.

For the VR technology hands-on session learners were required to experiment with two mobile VR simulated experiences of a fictitious BIM built pavilion environment constructed in Autodesk REVIT. Students were provided with Samsung S8 mobile phones and Samsung Gear VR virtual reality headsets and 5 minutes of onboarding related to the task and hardware use. The first experience saw learners experiencing the virtual BIM pavilion as a single user where they could navigate the environment, and watch the simulated transition of the real time lighting across 24 hours. In the second experience, the learners were placed in the same BIM environment only this time it had multiuser connectivity and voice chat enabled. The users could watch their self avatars and those of their fellow students in the environment. The learners had the same navigation and lighting system in place. This allowed for enhanced communication between the learners and the affordances associated with multiuser environments such as agency, perception and peer learning.

Learners were given 20 minutes for the AR session and 10 minutes each for the single-user and multi-user VR, respectively. When students completed their hands-on tasks, they could also experiment with the HTC VIVE and HoloLens technology. Students were then asked to complete a reflective essay on the experience linking it to the construction industry, which was completed two weeks after the session.

We used a qualitative research methodology involving two methods for conducting this research study. We used thematic analysis (Braun and Clarke, 2006) to examine the written reflections of the students. We classified the student's ideas to closely define categories based on our research question "How do learners perceive the interactive visualisation mode of a presentation delivered through mixed reality building information modelling and mobile pedagogy?" and concurrently categorised the emerging themes and sub-themes. We also used participant-observation (Jorgensen, 1989) to collect data during the lecture and two hands-on sessions about the interaction with the software as well as the visible responses of that interaction. We also noted if any of the students required additional help or guidance to complete the tasks.

Results and Discussion

The results of the analysis identified two general themes (learning and technology) and five sub-themes (learning engagement, learning experience, technology experience, technology readiness and technology future). Only one-third of the reflections discussed the learning, and almost all of them focused on technology which will require more onboarding about reflective practice in the follow-up sessions.

Data shows that students felt engaged during the session. They wrote about being involved with the activity and receiving feedback while conducting it, "in terms of the educational application, this extraordinary tutorial is a perfect example of its use in teaching as it gives us a more direct feeling of the design as an end-user." "Interestingly, we can "walk" in this VR environment by moving our feet in reality, and when the audio function turned on, I could hear someone talking in the "white house". Another example of engagement is a student stating: "Moreover, I could press the button in the equipment to "go" to the place I was looking at, while I could see other users at the same time in the application in the multi-user mode, and even communicate with each other via the …headphones." All this is in line with Jones, Ramanau, Cross & Healing (2010) learner's expectation of participatory, interactive, sensory-rich engagement by their environment. Furthermore, all of the students enjoyed the session and had unique experiences: "It was wonderful experience… It was like dreaming and imagination.", "This week we had an amazing experience with …, regarding the topic of how VR/AR can be used in the construction industry and the future.", "AR and VR technologies can alter our senses of reality." Clearly the students enjoyed the shift away from traditional delivery to self-direction, collaborative peer learning and technology-enhanced learning (Clark & Mayer, 2016).

For many of the students this was their first encounter with this kind of technology: “That was my first time to experience the AR/VR glasses”, “Since I am a tech-oriented people and have heard a lot about virtual reality, I was so glad to have the chance to use this new construction technology in the class.” “This activity introduced to me my first AR experience which I did not know the concept before, while this activity showed me that how the AR technology applied in daily life with a mobile phone instead of any high-tech equipment such as Google glasses, meaning it is easy to access and understand this technology.”, wrote one of the students, stating the affordability and accessibility of the technology. Sadler-Smith & Smith’s (2004) higher expectations for various inputs and individualisation were at met to a high degree, which in turn affords for productive learning outcomes that are effective at the same time.

Students showed a positive attitude towards the technology, even though most of them felt that it is not ready for widespread use, stating that “…this new kind of technology is not fully developed and still need time to be applied widely in the construction industry…”, “Both AR and VR are still in the developing stage.” and that “it is still not “perfect” enough.”. “I am convinced that although the details of the AR/VR software are still not perfect, this advanced technology will be improved and finally can benefit the construction industry and make the process more convenient and efficient.”, said one of the students, predicting the usefulness of the future improvements of these technologies. Many students also believed in changes that this technology will bring in the future, such as “I believe that it is a trend of development and it will have a profound effect on the whole society…”. “I believe that VR/AR will become an essential technology in the future, and I would like to follow this technology and learn more about this technology.” This aligns with views of Alexander et al. (2019) and Cochrane, Smart & Narayan (2018) that illustrate MR importance in higher education practice.

The students also appreciated the many possibilities of useful applications of these technologies: “this advanced technology will be improved and finally can benefit the construction industry and make the process more convenient and efficient.”, “the future job opportunities in the construction industry would be changed by this technology. It is likely to require more IT stuff in the construction industry, as more things are involved in using VR or AR.” and “augmented reality and mixed reality, VR is set to become an integral part of the construction process from the architect’s office to the job site... AR/VR are one of the best technological advancements to happen in the construction industry because it streamlines every process involved in the project.”

Observation data supports the results from the analysis of the reflections. The students were engaged to a high degree within the activities, which is evidenced by them asking questions and giving various comments about the use and the possibilities of the technologies. The students were not afraid to express their enjoyment and excitement during and after the use of both technologies and share their experiences between their peers, with the lecturers and even the social networks. However, learners had many pre conceptions before the session that was reiterated by the course convener’s observation that stated, “Before the sessions most students believed that they already possessed some understanding of AI/VR/AR and their applications, but after using the technology most realised they didn’t have an understanding prior to the session”. Following the sessions, most students advised that their understanding of AI/VR/AR technologies and their applications had been significantly adjusted and improved. With students expressing that their preconceptions (particularly about the practical use of the equipment) were inaccurate prior to the session. It was also noted by the convenor that, “The authentic experience provided in the demonstration sessions was reflected in good knowledge retention compared to some other components of the subject.”

For the lecture the course convenor noted that “the enthusiasm and provocative presentation engendered strong engagement but for some of the [English second language] learners the amount of unfamiliar content and volume of information was difficult to process, leading to some engagement issues such as mobile phone use”. Some adjustment to the presentation sessions before the next offering will improve learning outcomes. During the VR hands-on, the observation showed that the learners were highly engaged and excited to use the technology. The single user experience ran smoothly with all learners completing the built environment navigation without assistance. The multiuser experience required several interventions with regards to the headphones and communication with the learners having to be prompted several times to communicate with each other. The focus which could be observed from a PC observer visualised in (Figure 3) projected on the screen noted that learners spent most of their time watching the avatars of the users and the movements rather than trying to communicate with each other. When communication took place it was more in relation to where the user was in the scene and the location to group together to see each other rather than specifics about the built environment. This will need to be adjusted in future iterations and supports the idea of very specific lesson scaffolding in VR environments.
For the duration of the mobile AR hands-on, observation showed that the behaviour of most of the students conveyed the impression that they were in the flow state and had an intense focus on the activity in hand. The students were completing the objectives of the mobile AR app in one take, without stopping or pause until the end

of the activity. Many students were going back and re-scanning the artworks looking for the hidden features. After the completion of the activity, meaningful discussions emerged between the students and also with the lecturer. These discussions were on the subject of the use of AR/BIM in construction and future applications.

Conclusions

The use of mobile MR and BIM in learning offers a supportive environment that compliments the learning outcomes by engaging the students and providing unique experiences throughout the learning process. The improvements in the learning aspect, improved attention, unique interactions, reducing the cognitive load and increased enjoyment are the core features of these techniques. Based on the results, we recommend further integration of these techniques in the courses offerings and delivery that will enable all these features for the learners in, and not limited to architecture, engineering and construction industry. The techniques should be adopted within the curriculum that will lead to enhanced learning environments and subsequently lead to better learning outcomes. For more conclusive results and more in-depth understanding of the benefits and optimization of the use of technologies to enhance learning, future works should also include longitudinal studies with larger sample size and comparison to a traditional delivery control group. That will investigate how the students' knowledge evolves in time influenced by using these techniques.

References

Alexander, B., Ashford-Rowe, K., Barajas-Murphy, N., Dobbin, G., Knott, J., McCormack, M., Pomerantz, J., Seilhamer, R., and Weber, N. (2019). Horizon Report: Higher Education Edition. Louisville, CO: EDUCAUSE.

Birt, J., & Cowling, M. A. (2018). Assessing mobile mixed reality affordances as a comparative visualization pedagogy for design communication. Research in Learning Technology, 26, [2128]. https://doi.org/10.25304/rlt.v26.2128

Birt, J., Manyuru, P., & Nelson, J. (2017). Using virtual and augmented reality to study architectural lighting. In H. Partidge, K. Davis, & J. Thomas (Eds.), Me, Us, IT! Proceedings ASCILITE 2017: 34th International Conference on Innovation, Practice and Research in the Use of Educational Technologies in Tertiary Education (pp. 17-21).

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative research in psychology, 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Chan, A. P., Ma, X., Yi, W., Zhou, X., & Xiong, F. (2018). Critical review of studies on building information modeling (BIM) in project management. Frontiers engineering management. 5(3), 394-406. https://doi:10.15302/J- FEM-2018203.

Clark, R. C., and Mayer, R. E. (2016). E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning (4th ed.). New Jersey, NJ: Wiley. https://doi.org/10.1002/9781119239086

Cochrane, T., Smart, F., & Narayan, V. (2018). Editorial: Special Issue on Mobile Mixed Reality. Research in Learning Technology, 26. https://doi.org/10.25304/rlt.v26.2195

Jones, C., Ramanau, R., Cross, S., & Healing, G. (2010). Net generation or Digital Natives: Is there a distinct new generation entering university?. Computers & education, 54(3), 722-732. https://doi.org/10.1016/j.compedu.2009.09.022

Jorgensen D L. (1989). Applied Social Research Methods: Participant observation. Thousand Oaks, CA: SAGE Publications, Inc. https://doi.org/10.4135/9781412985376

Puolitaival, T., & Forsythe, P. (2016). Practical challenges of BIM education. Structural Survey, 34(4/5), 351- 366. https://doi.org/10.1108/SS-12-2015-0053

Sadler-Smith, E., & J. Smith, P. (2004). Strategies for accommodating individual styles and preferences in flexible learning programmes. British Journal of Educational Technology, 35(4), 395-412. https://doi.org/10.1111/j.0007-1013.2004.00399.x

Vasilevski, N., & Birt, J. R. (2019). Towards Optimizing Place Experience using Design Science Research and Augmented Reality Gamification. In A. Naweed, L. Bowditch, & C. Sprick (Eds.), Intersections in Simulation and Gaming: Disruption and Balance: Third Australasian Simulation Congress, ASC 2019, Gold Coast, Australia, September 2-5, 2019, Proceedings (pp. 77-92). (Communications in Computer and Information Science; Vol. 1067). Singapore: Springer. https://doi.org/10.1007/978-981-32-9582-7_6

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