TOWARDS A DIGITAL ERA IN AEC HIGHER EDUCATION: COMBINING THEORY AND TECHNOLOGY TO DEVELOP AND DELIVER ARCHITECTURAL MASTER CLASSES

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ABSTRACT: *In recent years, technology has been playing a transformative role in the field of built environment, architecture, and construction education. It can be argued that the emergence of digital technologies has revolutionised the approach to teaching and learning in higher education in these fields. Digital technologies, such as Artificial intelligence (AI), additive manufacturing, robotics, 3D laser scanners, and Immersive Realities (IR), have played a crucial role in enhancing sustainability and efficiency in the industry. However, the opportunities provided by the use of these technologies (as a single tool or combined) in higher education and within the field of Architecture, Engineering, and Construction (AEC) are still relatively unexplored. To address this gap, this work presents a novel pedagogical framework aimed to enhance students' literacy on emerging technologies, and increase their criticality, and understanding of professional practices along with the related ethical challenges. Furthermore, to assess its effectiveness regarding the integration of immersive VR technologies in the teaching practice, a learner-centred evaluation approach is proposed, based on the collection and correlation of both qualitative and quantitative data. Concerning the former, a dedicated questionnaire is developed to collect students' subjective feedback. For the latter, a method for tracking their use of space in the virtual environment is discussed. Both the immersive pedagogical framework and evaluation approach presented in this work will be implemented in diverse architecture and civil engineering master classes in Australia and in Italy, and their comparative outcomes and validation will be the object of future joint contributions.*

KEYWORDS: *Digital and Immersive Pedagogy; Digital Technology; Architectural Higher Education; Immersive Reality, Evaluation, Questionnaire, Spatial tracking.*

1. INTRODUCTION

Over the past decades, there has been a rapid growth in urbanisation and development of urban areas across the world. This has resulted in a considerable increase in the demand for new buildings, structures and infrastructures, which, in turn, brings along a number of environmental, social and economic challenges. The nature of such challenges has become increasingly complex, so much so, that the traditional and conventional methods of construction cannot address them. Emerging technologies and digital tools have been increasingly applied in this field to address such challenges and achieve a more sustainable, safe, efficient and optimized practice (Alsafouri & Ayer, 2018; Alsafouri & Ayer, 2019; Ardito et al., 2019; Davila Delgado, Oyedele, Beach, et al., 2020; Davila Delgado, Oyedele, Demian, et al., 2020; Fazel & Izadi, 2018; Hajirasouli & Banihashemi, 2022; Hajirasouli et al., 2022; Hamzeh et al., 2019; Mandolla et al., 2019; Moon et al., 2015; Nåfors et al., 2020; Rohani et al., 2014; Valero et al., 2015). Among such technologies, Immersive Realities (IR) such as Virtual Reality (VR) and Augmented Reality (AR) have proven to be very advantageous in various areas of built environment. When considering architecture discipline and the required spatial qualities, capabilities and understanding required for it, VR seems to be a more appropriate tool to incorporate in its pedagogy, with multiple advantages (Getuli et al., 2020; Hajirasouli & Banihashemi, 2022; Hajirasouli et al., 2022; Rahimian et al., 2019). Despite the emphasis that have been made by a number of studies and scholars regarding the development of digitally enhanced and technology-integrated teaching methods (Aydin & Aktaş, 2020; Bashabsheh et al., 2019; Ceylan, 2021; Hajirasouli

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& Banihashemi, 2022; Shirazi & Behzadan, 2015), a number of studies conducted by authors have identified that the current teaching and learning practices in the AEC higher education does not adequately embrace and incorporate such digitally enhanced methods and, therefore, are yet to respond to the industry's demand in this area (Getuli et al., 2020; Hajirasouli & Banihashemi, 2022; Hajirasouli et al., 2022; Pour Rahimian et al., 2019). More importantly, when developing such pedagogies, how would this affect students' perception of their education and impact their teaching and learning experience.

This study aims to provide an in-depth understanding of student's needs and requirements and, more importantly, their perception of the integration of new technologies in their courses and curriculum. For this purpose, in Section 2, a theoretical framework was developed to establish a novel immersive pedagogy. Building on the constructivist assumption of active learning for a digitally enabled pedagogy, a problem-based learning process fostered by immersive technologies is conceptualized. Furthermore, to assess the framework's effectiveness, an original mixed method for the evaluation of VR-based teaching experiences for AEC students is discussed in Section 3. This comprises a dedicated questionnaire to be administered to the students after the immersive learning experiences to collect their subjective perceptions and feedback. Complementarily, the tracking of their virtual position and its restitution in the form of contextualized heatmaps is proposed to objectively evaluate their use of the virtual environment in relation to the learning objectives. In Section 4, the implementation plan of the proposed pedagogical framework and evaluation method is then presented with reference to the architecture and civil engineering master classes which will be involved both in Australia (Western Sydney University) and Italy (University of Florence). Eventually, the discussion of the limitations and outlook of this study is provided in Section 5.

2. PEDAGOGICAL FRAMEWORK

To develop the proposed theoretical model a critical literature review was conducted, including the relevant works related to previously developed models in this area. From their analysis, constructivism philosophy emerges as the most appropriate teaching philosophy to be adapted to this framework, due to the constructive nature of immersive technologies and their implementation in teaching and learning activities. In fact, constructivism philosophy is correlated with creating and constructing new knowledge based on the learner's already existing knowledge, therefore implying an active and continuous participation in the process of learning (Behzadan et al., 2015; Behzadan et al., 2011; Biggs & Tang, 2007; Bruning et al., 1999; Lord, 1999; Luo & Mojica Cabico, 2018; Tynjälä, 1999; Von Glasersfeld, 1995). Hence, the constructivist approach was used as the principal philosophy for the developed model.

Choosing the right approach for implementing this model was the next step of this work. It is suggested that the concept of digital pedagogy does not only reflect upon using digital tools and technologies, rather, it is also about cautiously considering their effects and implications from a critical pedagogical point of view. Therefore, the decision about their integration within the teaching approach or not, depends on the desired learning outcome of a course or subject (Anderson, 2020; Barber et al., 2015; Croxall, 2013; James & Pollard, 2011). Problem-based learning approach was also used in this model as an integral part of the application and integration of immersive technologies. The selection of this approach was also due to its suitability for complex real-world situations where there is no right or wrong answer to the problem (Barber et al., 2015; Savin-Baden, 2007; Word, 2003), which is the main focus of AEC discipline and industry. This approach helps students to work collaboratively in groups, to identify the problems and gaps, and to develop solutions and knowledge, through self-directed processes (Barber et al., 2015; Savin-Baden, 2007; Word, 2003).

Eventually, immersive learning was also used as the last stage of this model. Using this method, the creation and construction of knowledge occurs through virtual immersion into a context, dialogue and/or situation. Immersion occurs in two different ways: immersion through narrative (cognitive aspects), and immersion through technological devices (technical aspects). This study focuses on immersion through technical devices, hence requires various tools and technologies, such as AR, VR, and Virtual Learning Environment (VLE). The choice of tools and technologies in this model depends upon the level of immersion required for a learning objective. VR, which is the subject of this study, is mainly being used when a fully immersive experience and a sense of presence in the virtual environment is required for the learning process.

3. IMMERSIVE VR LEARNING EXPERIENCE EVALUATION

The proposed pedagogical approach theorises the beneficial impact that the adoption of immersive visualization technologies can provide in AEC master classes. To support this claim and assess its effectiveness in upcoming case study implementations (see Section 4), an original method for the evaluation of immersive VR learning experiences is developed, considering both qualitative subjective data and quantitative objective observations. As shown in Figure 2, a questionnaire to be administered to the student after the immersive experience and divided into five inquiry areas is provided. Besides, the student's use and understanding of the virtual environment in relation to the learning objectives is evaluated with the acquisition of their spatial track during the VR experience and its sequential visualization of a BIM environment in the form of a heatmap.

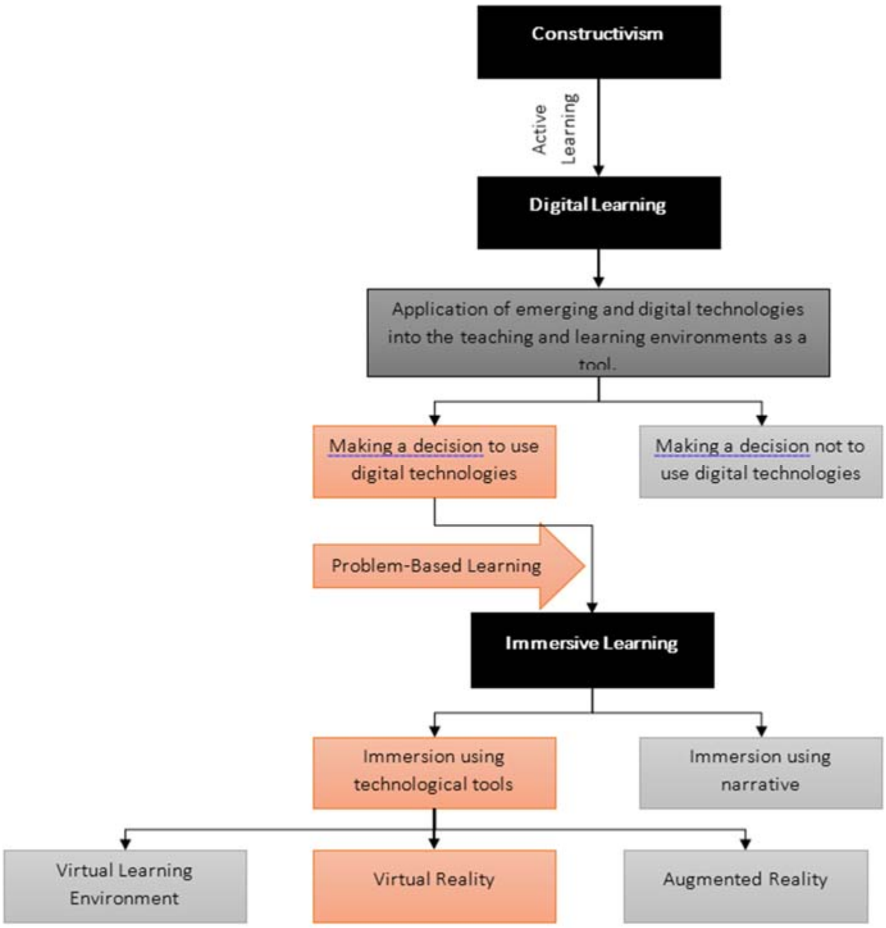

Fig. 1: Pedagogical framework designed for BIM-enabled VR-based technology application into architectural design studio.

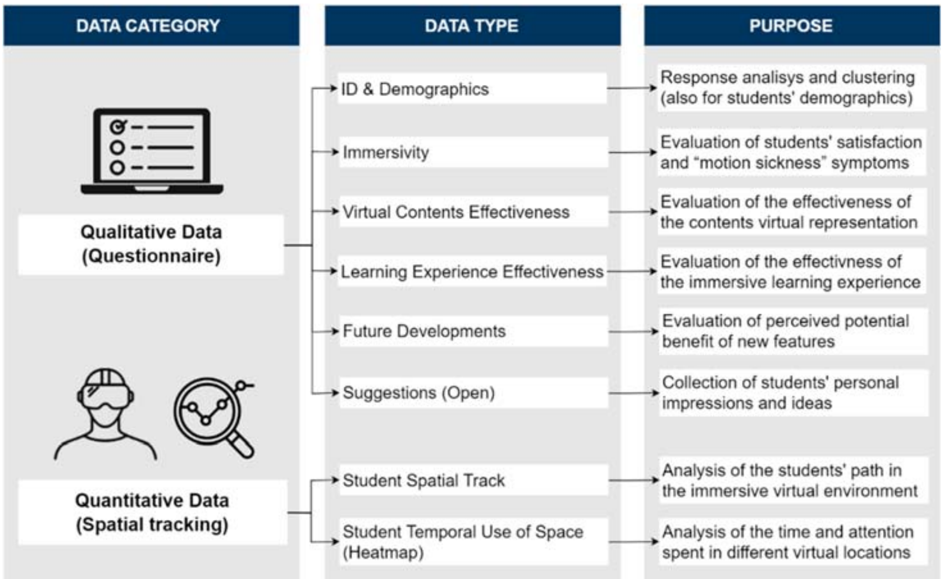

Fig. 2: Immersive VR learning experience evaluation approach – Data schema.

3.1 Post-experience evaluation questionnaire

To collect students' subjective feedback, a dedicated questionnaire has been developed to be administered directly after the immersive learning experience. First, data necessary to classify, analyse and classify the questionnaire responses based on students' demographics are collected. Then the experience is evaluated against the student's perceptions, concerning: the engagement with the virtual environment (*immersivity*); the reproduction of the virtual contents (*contents effectiveness*, e.g., graphical realism compared to the objective of the session); the gained self-efficacy and competency (*learning experience effectiveness*); the opinion on suggested additional features that could be implemented in the experience and that were currently missing (future developments). For the cited criteria the responses are collected according to a scoring system ranging from one to five, where five correspond to the maximum agreement with the statement or satisfaction with the experience. Furthermore, an open textual field (*suggestions*) is provided to enable the collection of personal remarks, impressions, and ideas, involving and empowering the student in the improvement and evolution of a learning approach based on ever-changing technologies and that will need to keep up to learners' expectations and needs to be future proof. In Table 1 the data type and the description and purpose of data collection are reported along with explanatory examples.

Table 1: Questionnaire data type description and prompt example

Data type	Description	Example
ID & demographics	Data necessary to analyse and classify the responses collected through the questionnaires with reference to the occurred immersive learning experiences, and to cluster their results also with reference to the students' demographics (anonymized). [Various]	Questionnaire ID: (Text) Immersive experience: (Text) Date: (yyyy/mm/dd) Age: (Number) Gender: (Multiple options) Course: (Text)
Immersivity	Questions related to the student's ability to get immersed in the virtual experience. They are useful for assessing how engaged the students were in the virtual world and to evaluate their satisfaction in terms of both ease of use and comfort (also related to the possible onset of symptoms of "motion sickness"). [Single rating – Likert scale]	How much did you like the experience? [min 1; max 5]
Contents effectiveness	Questions regarding the virtual representation of the learning contents, aimed at evaluating the effectiveness of the experience against the objectives of the session. [Single rating – Likert scale]	How efficiently and clearly does the content of VR help you to perceive the discussed subject better? [min 1; max 5]
Learning experience effectiveness	Questions pertaining to the overall effectiveness of the experience, aimed at investigating the actual usefulness of the immersive VR learning session compared to traditional methods, especially concerning the learning objectives. [Single rating – Likert scale]	Do you think this experience is useful in understanding the qualities of the designed spaces? [min 1; max 5]
Future developments	Questions concerning the introduction of new features (e.g., content animations, audio and visual effects, etc.) or virtual content aimed at enhancing the immersive VR learning experience through the inclusion of greater realism and/or interactivity. [Single rating – Likert scale]	Would you like to be able to grasp and interact with objects in the VR environment? [min 1; max 5]
Suggestions	Open questions to collect personal impressions and ideas from the students. [Text box]	Suggestions

3.2 Student's spatial tracking and use of space visualization

In the previous paragraph, it has been discussed how the students are actively involved in providing data for a qualitative evaluation. Here, the second, complimentary, data acquisition method is presented which is based on the objective observation of the virtual positions covered by the students throughout the experience. In turn, this involves capturing the position of the student in the VR environment during the entire course of the simulation in order to analyse their actual use of the tridimensional space. For this purpose, the student's virtual position shall be recorded with a data acquisition rate of at least 1 Hz. The 3D point sequence resulting from this process shall be transferred in a BIM environment and converted for the generation of heatmap visualization, within which the position of the student is represented, weighted by the time spent, with a colour gradient. In this way, the relevance of different areas of the experience can be evaluated based on the time spent in certain virtual locations by the students. As with the questionnaire's development, the student spatial tracking and visualization procedure to be performed during the learning experience is explained with reference to the collected data type in Table 2.

Table 2: Student's spatial tracking and use of space visualization characteristics

Data type	Description	Example
ID & demographics	See Table 1.	See Table 1.
Learning experience duration	The duration of the experience from start to finish, excluding a possible tutorial or time required to the student to get used with the immersive VR system and controllers. This is necessary to allow for the later heatmap visualization of the student use of the virtual space weighted on the overall elapsed time. [time in seconds]	Duration: (number) sec
Student spatio-temporal track	The student position in the virtual environment is collected as 3D point with 1 Hz frequency. The corresponding spatial track is then graphically represented against a model of the experienced environment (e.g., BIM model) both as a 3D path (polyline) and with an heatmap representation, with the colour gradient weighted on the time spent in a certain location.	Colour gradient representation of the student's followed path (weighted by time) [min. green, max. purple]

4. FRAMEWORK IMPLEMENTATION PLAN

The theoretical approach of this paper is built upon previous research projects, undertaken by authors in Australia and Italy, to create an innovative approach and prototype protocol for the design, delivery and evaluation of a number of subjects for AEC students in higher education, based on an interactive and immersive learner-centred approach. The outcome of this work will be implemented in a number of course subjects at the University of Florence, Italy and Western Sydney University, Australia. The nominated subjects for the implementation of this model are reported in Table 3.

Table 3: Immersive VR learning approach for AEC higher education - Implementation plan

Institution	Course (Academic Year 2023/2024)	Expected attendees
Western Sydney University, Australia	• Advanced Design Communication (ARCH7007) • ARCH7015 Practice Research Studio Civic (ARCH7015)	50 50
University of Florence, Italy	• BIM and Information Modeling of the Construction Process (B028836) • Design and Safety of Workplaces B030584 (B063)	50 50

The implementation of the proposed pedagogical model will engage the students in providing indications and opinions regarding the environment in which they are exploring and studying. This approach will help with validating both the pedagogical framework, as well as, the designed environments, by gathering the user's experiences and observations. This, in turn, will assist in enhancing the entire framework developed in this study. For this purpose, and according to the principles discussed above, a prototypical questionnaire implementation comprising 16 questions has been developed and is represented in Figure 3.

In addition to the questionnaire, a prototypical implementation of the student spatial tracking restitution in form of heatmap is proposed in Figure 4. As it can be seen, the more relevant areas of the virtual environment for learning purpose could straightforwardly be inferred based on the time spent, providing useful information in the development of further immersive teaching material (e.g., virtual environments).

Student Data	
ID:	
Age:	
Course:	
Gender:	

	Questionnaire	min - max
Immersivity	1) Did you enjoy the experience?	1 2 3 4 5
	2) Were you comfortable during the experience?	1 2 3 4 5
	3) Was it easy to use the viewer and controller?	1 2 3 4 5
	4) Did it bother you not being able to see your body in the virtual world?	1 2 3 4 5
Contents' Effectiveness	5) Are the signal arrows helpful in figuring out where to go?	1 2 3 4 5
	6) Does the virtual building spaces sufficiently replicate the real one?	1 2 3 4 5
	7) Did you need less time to understand the content displayed in VR compared to a face-to-face power-point presentation?	1 2 3 4 5
	8) Were your learning skills affected by the VR experience?	1 2 3 4 5
	9) Do you think this experience can replace the role of the educator?	1 2 3 4 5
	10) Do you think this experience is useful in getting to know a subject before it is explained to you by an educator ?	1 2 3 4 5
Learning Experience's Effectiveness	11) Do you think this experience is useful in understanding the building and its technological aspects?	1 2 3 4 5
	12) Is this type of learning useful for an inexperienced student?	1 2 3 4 5
	13) Is this type of learning useful for a student without any knowledge on the subject?	1 2 3 4 5
	14) Do you prefer to interact with an avatar or a teacher?	1 2 3 4 5
Future Development	15) Would you like to listen audio explanations of the virtual scenarios?	1 2 3 4 5
	16) Would you like to be able to interact with virtual objects?	1 2 3 4 5

Suggestions

Fig. 3: Immersive VR learning session evaluation questionnaire – Implementation prototype.

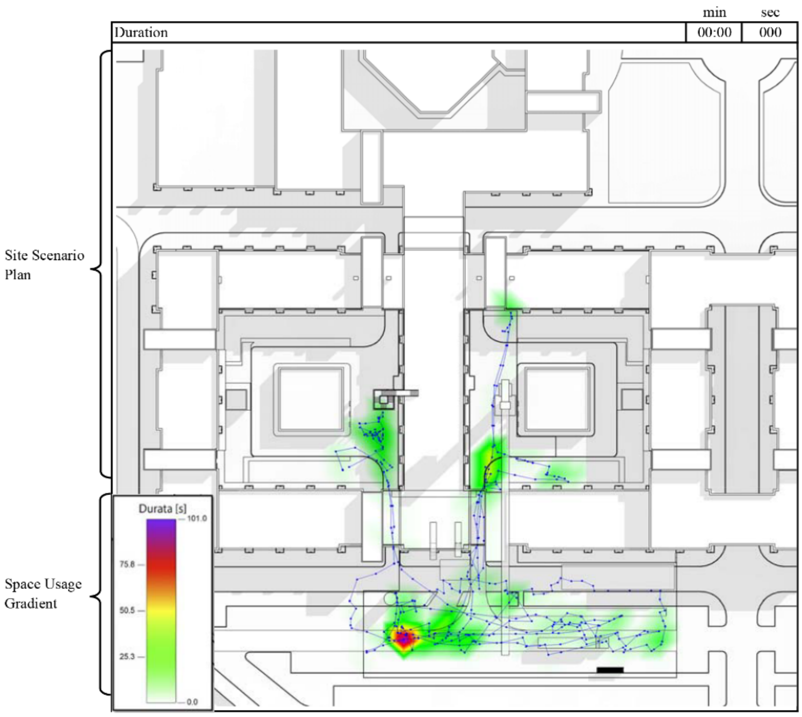

Fig. 4: Student spatial track heatmap representation – Implementation prototype

5. CONCLUSIONS

This study, which was a successful collaboration between University of Florence and Western Sydney University aimed to provide a comprehensive understanding of student's perception and demand of the newly developed pedagogical framework. This framework aimed to create a more engaging learning environment, while responding to the industries needs and requirements, and prepare students for the future of their careers in AEC. To achieve this, this study was developed in two stages. In stage one, a qualitative approach was used to develop a novel pedagogical framework, based on the constructivism method, followed by a problem-based approach and immersive learning method. To test the effectiveness of this developed model and student's perception of it, a mixed-method approach was used to develop an in-depth questionnaire. Furthermore, a contextualized heatmap recording is accompanying the developed survey to ensure the robustness of the results of this study.

The outcome of this research will be tested internationally at the architecture and civil engineering master classes which will be involved both in Australia (Western Sydney University) and Italy (University of Florence) in early 2024. The outcome of the experiment will form another joint publication and collaboration between the two institutions.

REFERENCES

Alsafouri, S., & Ayer, S. K. (2018, 2018/02/01/). Review of ICT Implementations for Facilitating Information Flow between Virtual Models and Construction Project Sites. *Automation in Construction, 86*, 176-189. https://doi.org/https://doi.org/10.1016/j.autcon.2017.10.005

Alsafouri, S., & Ayer, S. K. (2019). Mobile Augmented Reality to Influence Design and Constructability Review Sessions [Article]. *Journal of Architectural Engineering, 25*(3), Article 04019016. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000362

Anderson, V. (2020). A digital pedagogy pivot: re-thinking higher education practice from an HRD perspective. *Human Resource Development International, 23*(4), 452-467.

Ardito, L., Petruzzelli, A. M., Panniello, U., & Garavelli, A. C. (2019). Towards Industry 4.0: Mapping digital technologies for supply chain management-marketing integration. *Business Process Management Journal*.

Aydin, S., & Aktaş, B. (2020). Developing an Integrated VR Infrastructure in Architectural Design Education. *Frontiers in Robotics and AI, 7*.

Barber, W., King, S., & Buchanan, S. (2015). Problem based learning and authentic assessment in digital pedagogy: Embracing the role of collaborative communities. *Electronic Journal of E-Learning, 13*(2), 59-67.

Bashabsheh, A. K., Alzoubi, H. H., & Ali, M. Z. (2019). The application of virtual reality technology in architectural pedagogy for building constructions [Article]. *Alexandria Engineering Journal, 58*(2), 713-723. https://doi.org/10.1016/j.aej.2019.06.002

Behzadan, A. H., Dong, S., & Kamat, V. R. (2015). Augmented reality visualization: A review of civil infrastructure system applications [Article]. *Advanced Engineering Informatics, 29*(2), 252-267. https://doi.org/10.1016/j.aei.2015.03.005

Behzadan, A. H., Iqbal, A., & Kamat, V. R. (2011). A collaborative augmented reality based modeling environment for construction engineering and management education. Proceedings of the 2011 winter simulation conference (WSC),

Biggs, J., & Tang, C. (2007). Teaching for quality learning at university Maidenhead. *Berkshire, UK: McGraw-Hill Education*.

Bruning, R. H., Schraw, G. J., & Ronning, R. R. (1999). *Cognitive psychology and instruction*. ERIC.

Ceylan, S. (2021). A classroom experience on the use of virtual reality as a tool for representation in architectural education [Article]. *Design Principles and Practices, 15*(1). https://doi.org/10.18848/1833-1874/CGP/V15I01/1-17

Croxall, B. (2013). DH2013: The Future of Undergraduate Digital Humanities.

Davila Delgado, J. M., Oyedele, L., Beach, T., & Demian, P. (2020). Augmented and Virtual Reality in Construction: Drivers and Limitations for Industry Adoption [Article]. *Journal of Construction Engineering and Management, 146*(7), Article 04020079. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001844

Davila Delgado, J. M., Oyedele, L., Demian, P., & Beach, T. (2020). A research agenda for augmented and virtual reality in architecture, engineering and construction [Article]. *Advanced Engineering Informatics, 45*, Article

101122. https://doi.org/10.1016/j.aei.2020.101122

Fazel, A., & Izadi, A. (2018, 2018/01/01/). An interactive augmented reality tool for constructing free-form modular surfaces. *Automation in construction, 85*, 135-145. https://doi.org/https://doi.org/10.1016/j.autcon.2017.10.015

Getuli, V., Capone, P., Bruttini, A., & Isaac, S. (2020). BIM-based immersive Virtual Reality for construction workspace planning: A safety-oriented approach. *Automation in Construction, 114*, 103160. https://doi.org/10.1016/j.autcon.2020.103160

Hajirasouli, A., & Banihashemi, S. (2022). Augmented reality in architecture and construction education: state of the field and opportunities. *International Journal of Educational Technology in Higher Education, 19*(1), 1-28.

Hajirasouli, A., Banihashemi, S., Drogemuller, R., Fazeli, A., & Mohandes, S. R. (2022). Augmented reality in design and construction: thematic analysis and conceptual frameworks. *Construction Innovation*(ahead-of-print). https://doi.org/https://doi.org/10.1108/CI-01-2022-0007

Hamzeh, F., Abou-Ibrahim, H., Daou, A., Faloughi, M., & Kawwa, N. (2019). 3D visualization techniques in the AEC industry: The possible uses of holography [Article]. *Journal of Information Technology in Construction, 24*, 239-255. https://doi.org/10.36680/j.itcon.2019.013

James, M., & Pollard, A. (2011). TLRP's ten principles for effective pedagogy: rationale, development, evidence, argument and impact. *Research Papers in Education, 26*(3), 275-328.

Lord, T. R. (1999). A comparison between traditional and constructivist teaching in environmental science. *The Journal of Environmental Education, 30*(3), 22-27.

Luo, X., & Mojica Cabico, C. D. (2018). Development and evaluation of an augmented reality learning tool for construction engineering education.

Mandolla, C., Petruzzelli, A. M., Percoco, G., & Urbinati, A. (2019). Building a digital twin for additive manufacturing through the exploitation of blockchain: A case analysis of the aircraft industry. *Computers in Industry, 109*, 134-152.

Moon, D., Kwon, S., Bock, T., & Ko, H. (2015). Augmented reality-based on-site pipe assembly process management using smart glasses. ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction,

Nåfors, D., Berglund, J., Gong, L., Johansson, B., Sandberg, T., & Birberg, J. (2020). Application of a hybrid digital twin concept for factory layout planning [Article]. *Smart and Sustainable Manufacturing Systems, 4*(2), Article 20190033. https://doi.org/10.1520/SSMS20190033

Pour Rahimian, F., Chavdarova, V., Oliver, S., Chamo, F., & Potseluyko Amobi, L. (2019, 2019/06/01/). OpenBIM-Tango integrated virtual showroom for offsite manufactured production of self-build housing. *Automation in Construction, 102*, 1-16. https://doi.org/https://doi.org/10.1016/j.autcon.2019.02.009

Rahimian, F. P., Chavdarova, V., Oliver, S., Chamo, F., & Amobi, L. P. (2019). OpenBIM-Tango integrated virtual showroom for offsite manufactured production of self-build housing. *Automation in Construction, 102*, 1-16.

Rohani, M., Fan, M., & Yu, C. (2014). Advanced visualization and simulation techniques for modern construction management [Article]. *Indoor and Built Environment, 23*(5), 665-674. https://doi.org/10.1177/1420326X13498400

Savin-Baden, M. (2007). Challenging models and perspectives of problem-based learning. In *Management of change* (pp. 9-29). Brill Sense.

Shirazi, A., & Behzadan, A. H. (2015). Content Delivery Using Augmented Reality to Enhance Students' Performance in a Building Design and Assembly Project. *Advances in Engineering Education, 4*(3), n3.

Tynjälä, P. (1999). Towards expert knowledge? A comparison between a constructivist and a traditional learning environment in the university. *International journal of educational research, 31*(5), 357-442.

Valero, E., Adán, A., & Cerrada, C. (2015). Evolution of RFID applications in construction: A literature review. *Sensors, 15*(7), 15988-16008.

Word, D. (2003). ABC of learning and teaching in medicine. Problem based medicine. *BMJ, 326*, 328-330.