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An infrastructure 3D-lab based on virtual visits at Call of Duty Warzone to Develop Student's Competencies During the COVID-19 Pandemic

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Abstract - The didactic methods in the teaching of Engineering, Architecture, and Construction (EAC) are changing. The use of Information and Communication Technologies (ICT) such as Building Information Modeling (BIM), Virtual Reality (VR), and if we add to this a video game such as Call of Duty: Warzone (CoD: WZ) for educational purposes, the benefits of this could be explored. Until now, the advantages of BIM, VR, and video games have been studied separately, however, there is no evidence of an approach that implements all three technologies. The research in this study consists of the development of a methodology for the implementation of a user-friendly application of the Infra-3D-Lab software with specific pedagogical objectives for EAC education. This study based on the development of high-tech educational tools aims to: 1) make more effective use of learning hours through playful interaction with BIM, VR, and CoD: WZ models; 2) improve skills and concepts that are difficult to explain theoretically and 3) evaluate the functionality of the learning environment. The implementation of this technological tool is developed in the context of EAC's national higher education programs at a university in Mexico. This study demonstrates the effectiveness of using a remote collaborative tool Infra-3D-Lab as a teaching method for EAC. Additionally, this study shows that the learning experience can be enhanced using other technology tools such as Unreal Engine and Revit.

Keywords – VR for education, BIM for education, CoD: WZ for education, engineering education, innovation in education, higher education

I. Introduction

Technology-enhanced learning (TEL) research has shown the benefits of using Information and Communication Technologies (ICT) in the learning process and as teaching tools [1]. Building Information Modeling (BIM) is possibly the most important and promising ICT applied in the engineering, architecture, and construction (EAC) industry [2]. BIM is a powerful, highly organized, and easy-to-use graphical interface that gives building designers the flexibility to visualize and control multiple features of a construction project throughout its entire life cycle [3], [4]. Some studies have shown the benefits of using BIM in higher education programs to improve the understanding of engineering concepts such as sustainable building design [5], [6], construction project management [7], [8], and collaborative projects [2]. One of the main dimensions of BIM is its implementation with Virtual Reality (VR) to simulate and interact within virtual environments of construction projects remotely [9]. If we add a video game that allows us to obtain initial data and evaluate the functionality of the learning, a tool like the one explained later could be created. It has been shown that VR can significantly positively impact the learning process as a reinforcement activity for the retention of abstract concepts [10] and to enhance the learning of concepts and procedures, that is, improve learning skills [11]. Therefore, there is a high potential in the combination and implementation of BIM, VR and CoD: WZ digital technologies for educational purposes. The digital characteristics of these technologies and the vast development of the Internet, allows the educational approach to be in diverse learning formats: face-to-face, online or hybrid. The benefits of using BIM, VR, and VG for educational purposes have been explored separately, however, there is no evidence of an approach that develops and implements all three technologies together. Furthermore, there is a lack of simplified BIM-VR or VR-VG teaching tools developed with specific learning objectives for EAC higher education programs. The research of this study is the first to create the framework for the development and implementation of a software tool that uses CoD: WZ-BIM-VR, which is easy to use and with specific pedagogical objectives for EAC education. This study is based on the development of this high-tech educational tool that aims to: 1) make more effective use of learning hours through playful interaction with BIM-VR-VG models, 2) improve understanding of concepts complex abstracts that are difficult to explain theoretically, and 3) evaluate the functionality of the learning environment. The implementation of this technological tool is developed in the context of EAC's national higher education programs at a university in Mexico.

II. Background

A. BIM, VR and VG in higher education

BIM is defined as a "digital representation of the physical and functional characteristics of any built object [...] that forms a reliable basis for decision-making" [4]. BIM is a computer simulation of the built environment for any of the life cycle stages of a construction project, such as planning, conceptual design, construction, operation, and End-of-Lifecycle (EoL) [4], [12]. One of the purposes of BIM is to virtually simulate the procedures, activities, and analyses of new and existing constructions to evaluate different design alternatives and the performance of the building [13]. A BIM model is a powerful virtual environment that provides clear information in an understandable way for designers and professionals [3]. Due to BIM's user-friendly features and accessibility to the public, some studios have integrated the use of BIM for engineering education. In their work Abbas et. al [7], developed a framework to provide guidelines for the integration of the use of BIM in higher education programs, revealing the potential benefits for the professional profile of students. In another recent study, Mikhailov et. al [14] implemented BIM technologies, such as a BIM modeler (Revit®) and Visual Programming Language (VPL), for the educational process of Design of the Architectural Environment (DAE). They concluded that BIM technologies are a positive enabler for educational design and affordable tools for engineering education. In his work, Zamora Polo et. al [15] developed a critical review of the literature to determine if BIM can be considered a Virtual Learning Environment (VLE) tool. The study concluded that BIM has the appropriate characteristics of a VLE in terms of competencies, pedagogical approach, and level of integration. In the last two years, some studies have been carried out to document the results and lessons learned in the implementation of BIM as a pedagogical tool for higher education courses such as sustainable development engineering [6], architectural design [16], construction, project design [17], among others. The results of all these studies position BIM as a promising technology to improve education and the learning experience in engineering. Another technology that has recently been incorporated into the educational environment is Virtual Reality (VR). VR developments are not new, but due to their potential applications in higher education, they have become very attractive to academics and universities. In their work, Radianti et. al [18] developed a comprehensive review of the literature on VR applications for higher education in recent years. The literature review focuses on effective learning, design elements, learning theories, and conditions for successful implementation. The study concludes that VR represents an effective pedagogical tool with the benefit that the technology is affordable to implement in universities and higher education centers. Video Games (VG), like VR, are not new tools in the educational field, however, they have been added as possible options in higher education. In educative terms, games are an environment where the content and the game itself facilitate and improve the acquisition of knowledge and skills to solve problems and challenges, based on learning focused on achievement. In this study, the objective is for students to practice solving a specific problem, obtain knowledge of certain content and improve one or more skills.

B. E-learning engineering education and COVID-19 contingency

E-learning refers to the use of online learning and software-based learning; this term is interchangeable with online learning. E-Learning Systems have been defined as web or cloud-based software to assist in the teaching process [19]. Al-Fraihat et. al [20] defined an e-learning system as "an information system that can integrate a wide variety of instructional materials (via audio, video, and text media) delivered via email, live chat sessions, discussions, online, forums, quizzes, and assignments." The e-learning system is effective in supporting educational activities and the learning process. Furthermore, with the proliferation of technologies, their use, focus, scope, and impact have increased considerably. In higher education, the current global trend requires studying and teaching remotely due to mobility restrictions [19]. Therefore, educational systems around the globe have converted to a full e-learning format that shows good results in terms of learning experience and adaptability. The proposed study is carried out within the framework of the development and implementation of the new Tec-21 educational model at the Tecnológico de Monterrey higher education institution in Mexico. The implementation approach was adapted to an emerging and flexible digital mode due to the contingency of the international COVID-19 pandemic [21]. The digital and flexible model proposes various innovative solutions for e-learning, such as the use of (asynchronous) video classes, teleconferences, the flipped classroom model, and supporting educational platforms (for example, Canvas®).

C. The knowledge gap

Although the benefits of using BIM, VR, and VG for education have been explored in-depth, research is fragmented, therefore there is no evidence of an approach that develops and implements all three technologies together. The development of a didactic and simplified Infra-3D-Lab tool with specific learning objectives for higher education programs for EAC is missing. Due to the current conditions of international contingency, e-learning tools for engineering must be developed to improve the learning environment at home.

III. Methodology

This methodology was implemented in the hydraulic works course of the civil engineering program. To have a reference of whether the methodology works, a Control-Group (CG) of 30 students was provided, which solved the same case study as the Experimental Group (EG) with which the Infra-3D-Lab methodology was used. The application to CG has three main stages (Fig. 1). In the first stage, the details of the case study and the data available were reviewed. The next stage consisted of reviewing the existing literature to solve the case study and collect the missing data, with these data the hydrological and hydraulic designs were made. And, finally, stage number three, consisted of making sustainable proposals for the design made in the previous stage. At the end of each of the stages, surveys were applied to measure the perception of the students.

As mentioned before, the Infra-3D-Lab methodology was also applied for the Experimental Group (EG) and consisted of 4 stages (Fig. 2). The first two stages are the same as the CG, however, in stages 3 and 4 a CoD: Wz-BIM-VR toolkit was developed (in that order) to obtain and process data (stage 3) and perform a 3D modeling (stage 4) for the creation of a user-friendly educational platform (Hydr-3D-Lab) to apply hydraulic concepts and describe construction processes in a virtual environment. The toolkit was developed using specialized software. In the first place, the VG Call of Duty: Warzone® (CoD: WZ) served as the main source of the data, later for the data capture Contextcapture® was used, and, finally, for the modeling and creation of sustainable proposals used BIM (Revit®) and VR (Unreal Engine®). Like the CG, at the end of each of the stages, surveys were applied to measure the perception of the students. As mentioned before, this educational tool was implemented in a course of the hydraulic works class for the EG of the civil engineering program. The educational tool was used for the development of a case study based on the VG CoD: WZ. The format of the course was completely online, considering mobility restrictions due to the COVID-19 pandemic. Class sessions were planned to have discussions about the conceptual content and work synchronously on this collaborative project, using the Infra-3D-Lab educational tool. This platform allowed the simultaneous participation of different students in a single master digital model, to interact synchronously.

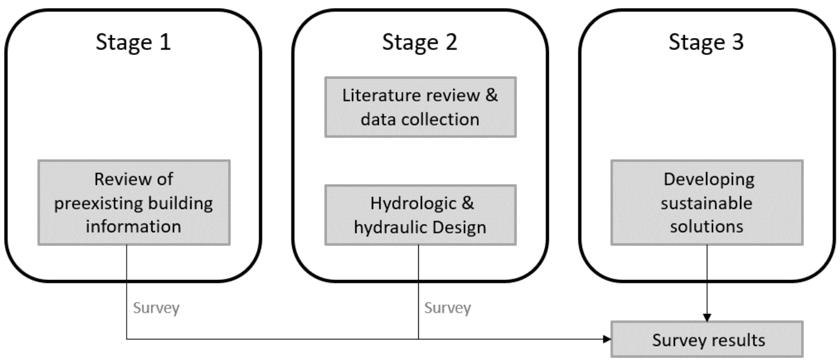

Fig. 1. Methodology of application of the tool for the Control-Group.

For the evaluation of the quality of the work carried out using the Infra-3D-Lab tool, a specific rubric was developed that covers the expected content and deliverables, as well as collaborative teamwork and the quality of the virtual model. For the evaluation of the results of the e-learning, an online end-of-project survey was carried out at the end of the activity to evaluate the knowledge of the students about the content of the conceptual, procedural course and their perception to improve their understanding using Infra-3D-Lab in a case study. To facilitate future improvement of the course, the end-of-project survey also included open-ended questions about your overall experience of the course and the project. 30 students completed the exit survey. According to the survey results, the use of Infra-3D-Lab as a platform for the collaborative project had a significant positive impact on the understanding of EAC concepts.

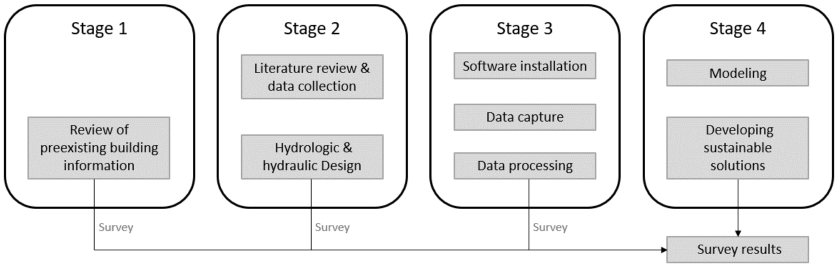

Fig. 2. Application methodology of the Infra-3D-Lab methodology for the Experimental-Group.

IV. CASE STUDY

A. Overview

The case study consisted of the hydrological and hydraulic evaluation of the risk of failure of a bridge located transversely in the course of a river that receives surface runoff from a mountain that captures rainwater and contributes to the melting that occurs in its upperparts. All information on land, areas, dimensions, and location is based on the VG Cod: WZ. The hydraulic and hydrological design methods used are those proposed in the study plan of the university where this methodology was applied. The VG CoD: WZ became very popular since its release date in the year 2020. It currently has more than 100 million players worldwide. In one of the game maps, in the northern area, the Gora Summit Bridge (GSB) was located (Fig. 3) and had infrastructure around it, for example, antennas, buildings, etc. The objective of the case study is to evaluate the possible failure of the GSB bridge caused by runoff from the surrounding mountain and, in this way, identify areas of opportunity to improve the design of the GSB, design hydraulic works to protect everything under the terms of sustainability. For the case study, the students had to analyze the virtual model of the current construction conditions using CoD: WZ and BIM and VR technology selected by the instructors. From the initial evaluation, the students identified the weaknesses of the GSB and proposed a comprehensive solution. The final solution was also developed using BIM and VR tools. The group was divided into groups of 5 students to develop their proposals.

Fig. 3. Panoramic view of the Gora Summit Bridge in the video game CoD:WZ.

B. Construction project assessment

All the geometric and technical information of the GSB was obtained by measurements in the VG CoD:WZ using the Contextcapture® software; by recording a video of the dam in Cod:WZ in a remote session with the students in Zoom®. The information was then shared with the students and different teams were created to focus their evaluation on a particular topic of interest that they considered relevant to solve. Of the six groups in the class, the students were interested in 3 main topics: 1) Hydraulic analysis and design, 2) Construction procedure, and 3) Characteristics of sustainable construction. For the hydraulic analysis and design, the students were interested in calculating the maximum runoff based on a proposed rainfall and designing hydraulic structures for protection, for example, channels, some curtains, or diversion, thus ensuring the proper functioning of the GSB. For the construction procedure, the students focused on the structural revision of the bridge in the face of possible undermining, sediment dragging, and runoffs that could compromise the foundation of the GSB, in addition to reviewing the construction processes in general, considering the optimal use of available resources. For the sustainable design features, students focused on analyzing the clean energy potential of the structure to propose improvements (e.g., the use of photovoltaic systems, thermosolar, and passive solar design). These studies were made using the selected software for BIM and VR tools. The students were beginners using these technologies; nevertheless, instructors developed video tutorials and selected the most reliable options to prepare an ideal toolkit for students.

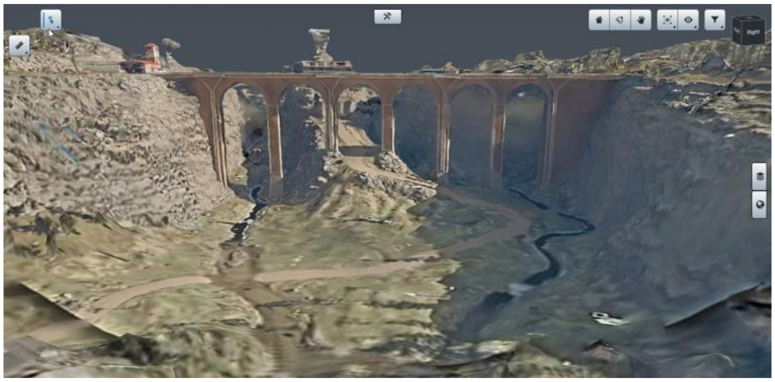

Fig. 4. Frontal view of the digital twin of the Gora Summit Bridge (GSB) generated in ContextCapture®.

Due to the inability to perform multiple inspections in CoD:WZ; because the in-game map was updated; and one of the main features was the disappearance of the GSB, the students, in coordination with the instructors, developed a digital twin of the GSB and created a Detailed 3D point cloud including existing topography. In addition, a scaling procedure was performed to make the digital twin completely realistic (Fig. 4). Subsequently, the point cloud was analyzed using the BIM Revit® software and the VR Unreal Engine® software. In this way, the students had the means to analyze every aspect of the bridge in an immersive way. Also, they were able to take a virtual tour and report any design details for future evaluation. Students were then capable to create an accurate BIM model of the GSB to perform the assessments described above. With the help of the collaborative function of the BIM VR software (Fig. 5), the instructors assisted in the modeling process, as well as in the evaluation and interpretation of the results.

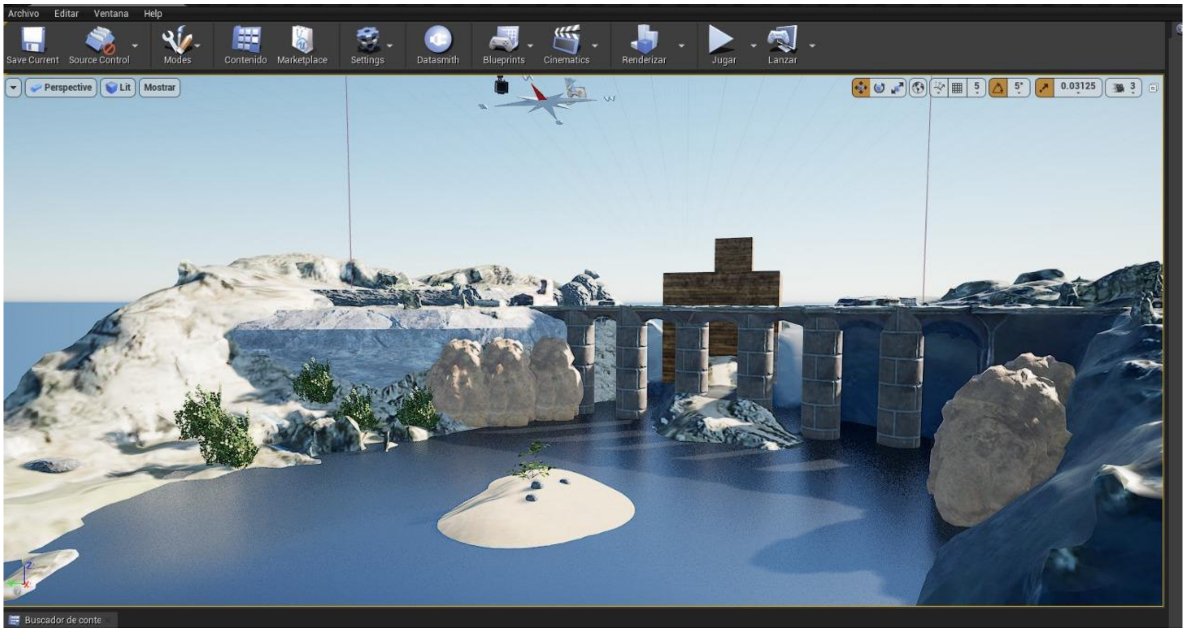

Fig. 5. Frontal view of the digital twin of the Gora Dam using Unreal Engine®.

C. Results

Students developed the assessments and proposed design improvements, then the final proposals were presented in a virtual event. The students developed a virtual reality model showing the improvements for the design covering all the necessary technical aspects. Attendees used their equipment for the VR experience (e.g., virtual reality goggles, smartphones, tablets). During the development of all the stages of the proposals presented, the Infra-3D-Lab methodology proved to be efficient for all the participants. The students enjoyed using these digital resources for the development of the projects, and the attendees were satisfied with the results and the use of technology to interact with the proposed solutions.

V. Discussion

The instructors; of the CG and EG group; evaluated each student and team. The specific competencies are defined in the course description. These were: C1-Communication; C2-Teamwork and relationships; C3-Problem-solving and C4-Critical thinking and environmental ethics (Fig. 6 and Fig. 7). The results were significant due to the difference between using and not using the Infra-3D-Lab methodology

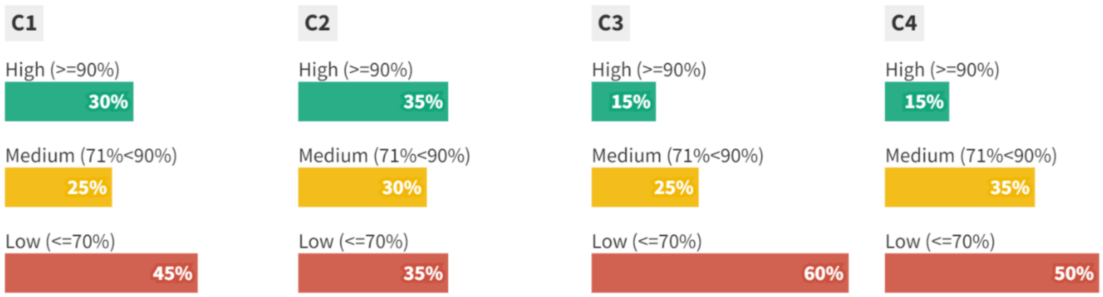

Fig. 6. Evaluation results for the Control-Group.

The quality of the final proposals was acceptable for the level of mastery of the students; to measure their perception of the design and results of the course, an end-of-project survey was also developed for both groups CG and EG. The objective was to assess the student's perception of the implementation of specialized technologies for infrastructure evaluation and design improvements. The results showed a positive impact on the students regarding the understanding of the course contents using the proposed technology. They also enjoyed using professional tools as teaching methods for understanding complex concepts during a difficult time of international health contingency. Many students reported that working remotely as a team was enjoyable and felt that the technology tools used, improved their performance individually and as a team. Figures 8 and 9 show the results of the end-of-project survey also for both groups CG and EG. Most students agreed that VG, BIM, and VR are powerful design tools that helped them better understand the different dimensions of the construction project (for example, custom design, design team coordination, assessment accuracy, conflict reduction).

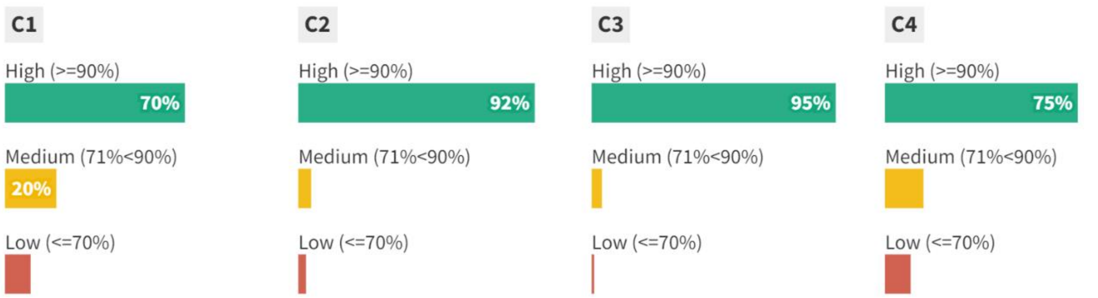

Fig. 7. Evaluation results for the Experimental-Group.

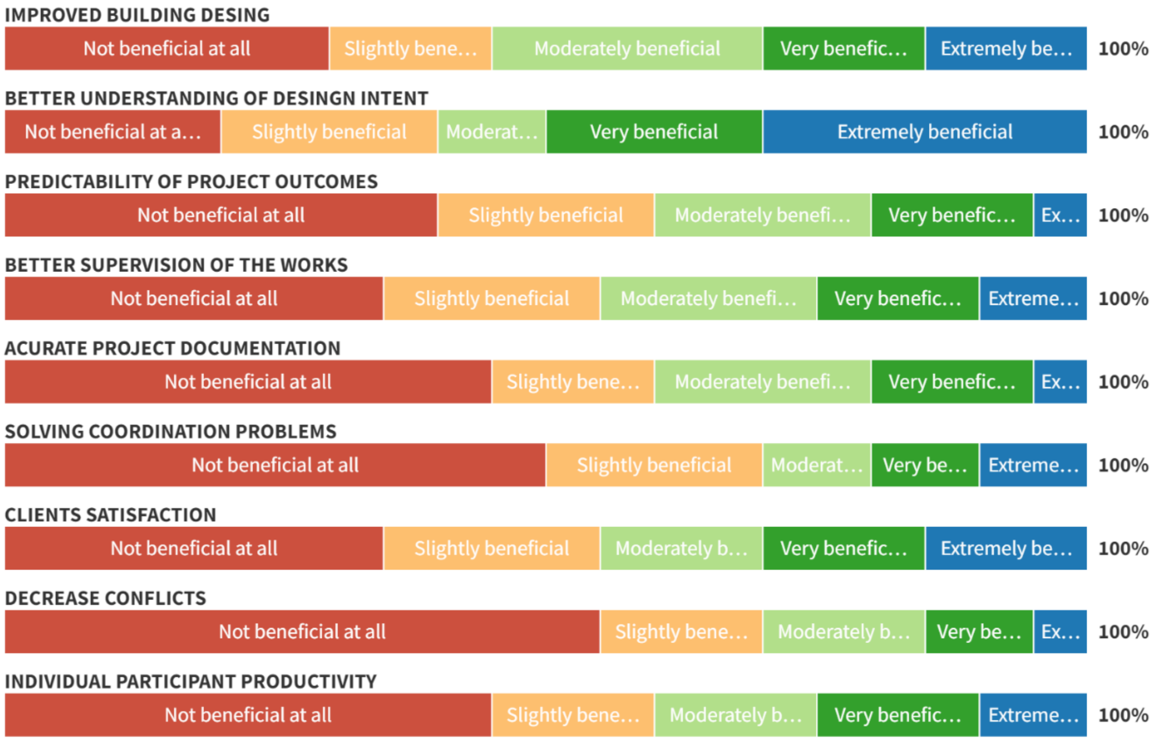

Fig. 8 Results of the end-of-project survey when using the Infra-3D-Lab methodology. Control-Group.

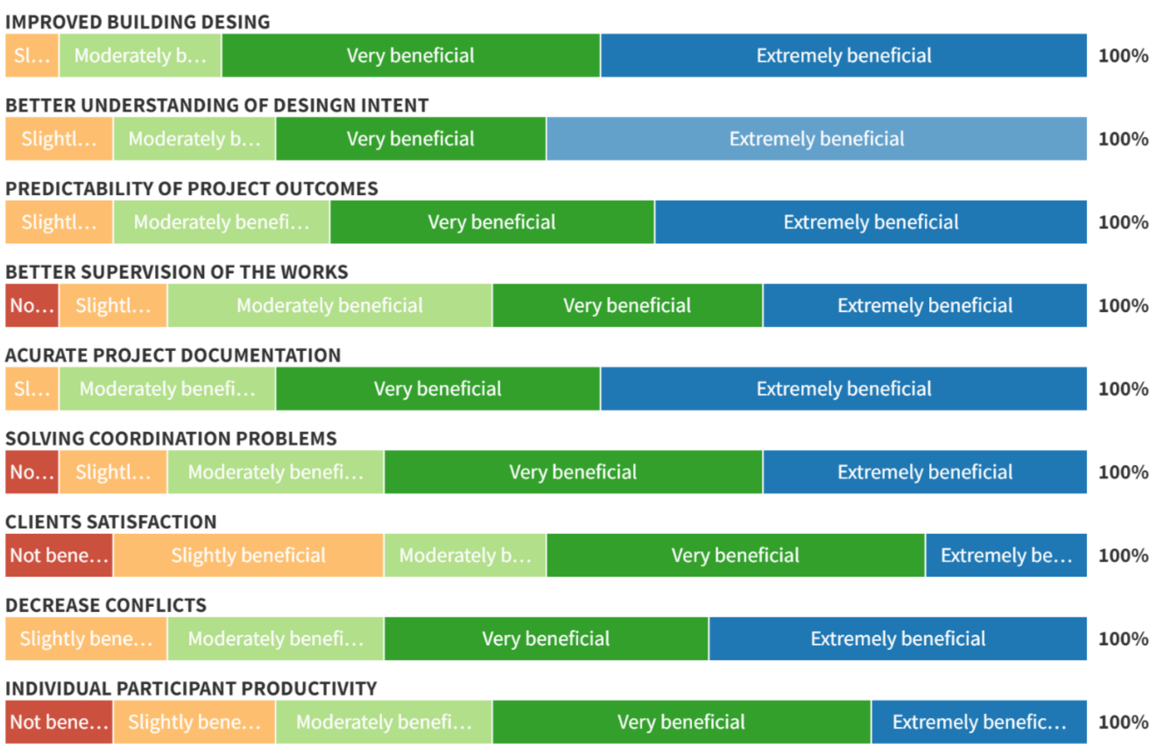

Fig. 9. Results of the end-of-project when using the Infra-3D-Lab methodology. Experimental-Group.

VI. CONSLUSIONS

This study investigates the role of VG-BIM-VR technology tools that facilitate the learning experience of students in EAC's higher education programs. This study demonstrates the effectiveness of using a collaborative Infra-3D-Lab tool as a teaching method for EAC. In a relatively short period (5 weeks), the students were able to develop virtual construction models with the desired quality. Additionally, students demonstrated understanding and engagement with complex ideas related to EAC design and ICT implementation. Furthermore, this study proves that the learning experience can be enhanced using this methodology. Infra-3D-Lab offers a powerful visual user interface that is easy to use, technically affordable, and realistic. With Infra-3D-Lab, users can manage a large amount of data embedded in the virtual models (e.g., geometry, materials, schedule, environmental impacts, hydraulic and structural analysis). All this information is interdependent and correlated with each other and with other external variables. Without a highly advanced organizational system like Infra-3D-Lab, it would not be possible to develop complex projects like academic activities to prepare students for real problems. This study presented the status of Infra-3D-Lab as a teaching method for EAC courses in a university in Mexico and formulated a framework that will provide guidelines to incorporate Infra-3D-Lab as a tool for efficient remote collaboration.

VII. ACKNOWLEDGMENTS

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