3D immersive learning in architecture and construction areas

Aprendizaje inmersivo 3D en el campo de la arquitectura y construcción

Gabriel Pérez [1*], Xavier F Rodríguez[1*], Josep María Burgués[1*], Marc Solé [2], Julià Coma[1*]

[1] Department of Computer Science and Industrial Engineering. Universitat de Lleida, C/Jaume II 69, 25001 Lleida, Spain. gabriel.perez@udl.cat; xavier.rodriguezpadilla@udl.cat; josemaria.burgues@udl.cat; Julia.coma@udl.cat*
[2] Invelon Technologies. info@invelon.com

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HIGHLIGHTS

- Immersive learning environments for architecture and construction.
- High teaching-learning capacity using virtual reality tools.
- The virtual reality as a tool for architectural design.

TITULARES

- Entornos inmersivos de aprendizaje de la arquitectura y la construcción.
- Alta capacidad de enseñanza-aprendizaje utilizando herramientas de realidad virtual.
- La realidad virtual como herramienta de diseño arquitectónico.

ABSTRACT

Beyond of BIM technology consolidation, the incorporation of virtual reality in the field of architecture and construction implies a new breakthrough which implies several advantages both at professional and academic levels. With the aim to measure the potential of this technology, a set of immersive activities were performed at the University of Lleida in the degree of Technical Architecture and Buildings. From the results, it could be observed the great ease of students in learning the use of virtual reality tools and the great potential of these solutions not only in learning architecture and construction but also as a professional working tool, especially for the design phases.

Keywords: *Immersive learning; Virtual reality; Building Information Modelling (BIM)*

RESUMEN

Más allá de la consolidación de la tecnología BIM, la incorporación de la realidad virtual en el campo de la arquitectura y la construcción implica un nuevo avance que conlleva varias ventajas tanto a nivel profesional como académico. Con el objetivo de medir el potencial de esta tecnología, se realizaron un conjunto de actividades inmersivas en el grado de Arquitectura Técnica y Edificación de la Universidad de Lleida. A partir de los resultados, se pudo observar la gran facilidad de los estudiantes para aprender el uso de herramientas de realidad virtual y el gran potencial de estas soluciones no solo en el aprendizaje de arquitectura y construcción, sino también como una herramienta de trabajo profesional, especialmente para las fases de diseño.

Palabras clave: *Aprendizaje inmersivo; Realidad virtual; Building Information Modelling (BIM)*

1. INTRODUCTION

Beyond of BIM technology consolidation, the incorporation of virtual reality in the field of architecture and construction, implies a new breakthrough which, among other advantages, will lead to a better interpretation of the data 3D with the consequent increase in quality and productivity, the design virtual pre-visualization at any time, the early detection of errors in the designs, the incorporation of other technicians and customers to the design process, etc. [1].

From the point of view of the learning process and methodologies, it is said that virtual environments can contribute to learning from multiple perspectives, such as improving comprehension, reducing learning time, and generating more lasting knowledge, among other [2].

By reviewing the research regarding the use of 3D virtual worlds in both K-12 and higher education settings until 2008, Hew (2010) found that virtual worlds may be utilised for the following uses: (1) communication spaces, (2) simulation of space (spatial), and (3) experiential spaces ('acting' on the world) [3].

Some authors highlighted the necessity to do research on learner's attitudes and the main challenges to be overcome when employing Virtual Reality Learning Environments (VRLE). Thus, topics such as the usability of the VR interface designs, the ability levels required to design a VR course, possible negative attitude toward learning in a VRLE, the current cost effectiveness of these technologies, and finally the effectiveness of using VR learning environments, must be further explored [4,5].

In a study conducted by Lindgren R et al. (2016), it was concluded that enacting concepts and experiencing critical ideas in physics through immersive, whole-body interactive simulation leads to significant learning gains, higher levels of engagement, and more positive attitudes towards science. The authors highlighted that these interactive environments also afford the opportunity to experience science phenomena from new perspectives that change the affective and motivational disposition of the learner [6].

Another previous research conducted by Nikolic et al. (2009), aimed at improving engineering education in building and construction by using interactive learning applications in an immersive virtual reality environment. It was found that the added interactivity in the designed Virtual Construction Simulator (VCS) helped students in developing higher-quality schedules and an enjoyable learning experience. The VCS implementation to encourage collaborative group work, engage students and foster greater solution generation through better visualization of construction processes has been proven [7].

In 2016, in the Higher Polytechnic School, and in particular in the Degree in Technical Architecture and Building, a process of implantation of the BIM (Building Information Modelling) methodology was started. The aim of this process was to train the students with the competencies and needed skills to successfully face their future incorporation into their professional career, in which methodologies based on 3D environments have begun to be compulsory (European Directive 2014/24 /EU European Parliament and Public Procurement Council).

Once the BIM methodology has been implemented in these degrees, with the inclusion of extended reality technologies, a new step forward is now coming. This phase involves the transition from the 3D BIM model to virtual reality, exploring future applications of this virtual environment both for teaching and professional purposes.

Virtual Reality (VR) and Augmented Reality (AR) are the three-dimensional (3D) representation of things through electronic means. Virtual technologies are making significant breakthroughs in activities such as the automation of design, training, training, simulation and visualization of scientific data, in several sectors as diverse as architecture and construction, automotive, medicine, among others.

Main benefits of using VR are a better interpretation of 3D data, an increase in the quality and volume of industrial productivity, a reduction in costs and an early detection of errors in designs. Thus, beyond its application in the video games sector, VR/AR is becoming a fundamental design tool in any field. In addition, design departments that use virtual reality can better position themselves as technology companies, gaining a more than positive reputation and offering their customers a very innovative way of viewing designs.

In the field of architecture and design, VR/AR allows users to pre-visualize projects in a very similar way as it would look in a particular location before being executed, fact that provides the advantage of detecting possible design errors, doing improvements, interacting with the virtual environment, etc. In this way, the architectural designs can be continuously improved and, also innovative, even risky, options can be used to evaluate more closely whether or not to go ahead with the construction phase. Virtual reality technology allows increasing the perception of volumes, reducing design mistakes in the architectural volumetric space definition phase. In addition, VR/AR gives the engineer-architect a correct sense of the proportion and scale of the building and also allows the client showing a preview at any time of the building without the need to build a mock-up.

Being possible to previously observe the design through VR, designers are able to detect possible errors and make modifications avoiding the need of redesigning and modifying it once built. In addition, the "time to market" is also reduced, increasing the agility and speed of projects execution.

In this context, this research aims to analyse the potential of VR as a teaching-learning tool in the Degree in Technical Architecture and Building at the University of Lleida. At the same time this research allows testing the specific tools for the Architectural field that are currently being developed by INVELON Technologies Company. Main purpose of these tools is to facilitate the interactions between users and virtual building, with the aim of improving and customizing designs.

2. MATERIALS AND METHODS

The presented study is part of the teaching innovation project "Immersive learning in 3D virtual environments (virtual reality and augmented reality)" promoted by the "Vicerectorate for Teaching, Quality and Innovation" at the University of Lleida. The main objective of this research on teaching project is to study the incorporation of virtual reality in the curricula of the degrees of Technical Architecture and Buildings as well as Industrial Engineering. On one hand, it was expected to study this technology as "teaching tool" for "immersive" learning, and on the other hand, as "design tool" in the fields of architecture and industrial engineering.

In a first phase of this project, a set of five activities and four consecutive surveys were conducted with a sample of 15 students belonging to the subject "Graphic Expression 3" of the degree in "Technical Architecture and Buildings" [8]. The virtual reality models used for the activities were the student-generated BIM models in the previous subject of Graphic Expression 2, which were transformed into virtual reality files for this specific purpose (Figure 1).

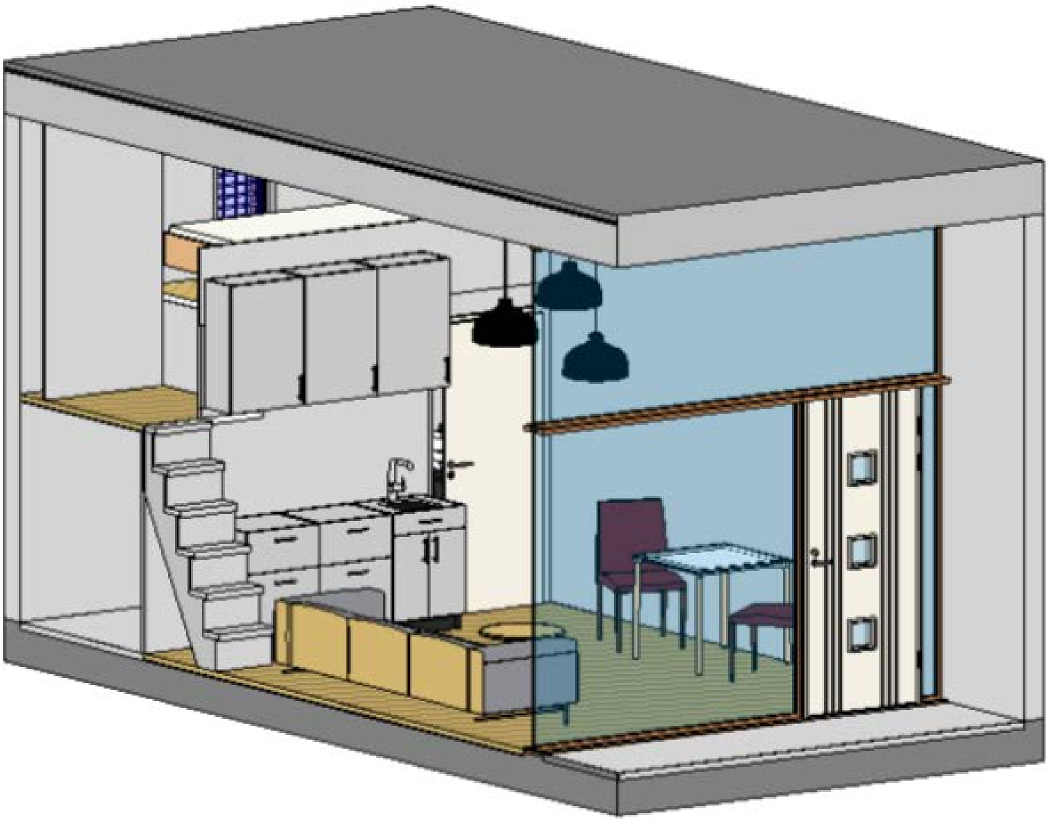


Fig. 1: *One of the student's BIM models transformed to VR models*

For the development of these field activities, the virtual reality models were generated, using Showbuilding tool by the company INVELON Technologies [9], from the BIM models created by the students. This Showbuilding tool allows the user interacting with the virtual architectural environment through a set of tools, such as measurements, changes of materials, addition and subtraction of furniture, advanced movements inside the model, changes of lighting, among others (Figure 2).

Fig. 2: *Showbuilding tool by INVELON [4]*

Main tools of Showbuilding tool are the following:

- Manual teleportation
- Teleport to specific rooms
- Modification of wall materials
- Modification of pavement materials
- Modification of artificial lighting
- Modification of natural lighting
- Distance measuring tool

Once the user is immersed in the virtual space of the building, he can select the tools by means of a tool palette available in the left control (left hand), and selecting them by shooting the selection ray with the right control (right hand).

In terms of hardware, two HP Z VR BACKPACK G2 computers, and HP REVERB glasses with drivers included, were used [10]. These "backpack" computers make the virtual reality experience more real than ever before in terms of the total mobility of the user (Figure 3).

Fig. 3: *Hardware used during the activity's development*

As one of the main goals was to study the learning process on the use of the tools as well as their behavior once immersed in virtual environments, a set of five activities was suggested (Figure 4):

- Activity 1. To modify the natural lighting, morning, afternoon and night.
- Activity 2. To move the dining room.
- Activity 3. To modify the floor material.
- Activity 4. To modify the wall material.
- Activity 5. To move to the entrance of the house.

These activities were performed twice, in 10-minute sessions. The first time the students entered to the models without any previous knowledge about the used Showbuilding solution tool. Two single-house architectural projects were used for the activities. One was a small double-floor single-house, and the second one was bigger than the former, with a more complex distribution, several rooms and a garden, placed in the same floor.

The second immersion was carried out a week later, having made in between an extra session of also 10 minutes in order to freely practice.

For each activity, the time that each user needed to complete the action was measured, as well as whether or not it was necessary to give help at 40 seconds from the beginning. The action was considered as successful if it was done in less than 60 seconds.

In order to compare the times needed to complete the actions, a reference user was used, who had prior knowledge of using the tool. In addition, in a previous estimation, it was considered that each of the actions could be accomplished by an experienced user in a maximum of 5 seconds.

A set of four surveys were also conducted, at the beginning and after each session, in order to know about the feelings, knowledge acquired and perception about the technologies used in these sessions.

Fig. 4: *One student during the activities development*

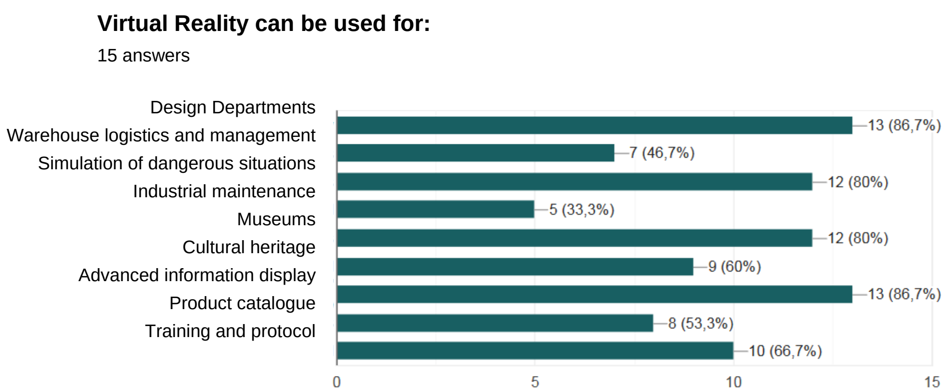
3. RESULTS AND DISCUSSION

The main results from the activities are summarized in Table 1. User number 15 was an experienced user who served as a reference to get an idea of the necessary time to complete each activity. As expected, this user needed around 5 seconds to complete the different activities.

If a user needed help after 40 seconds from the beginning, a Y (Yes) was marked, and if he did not complete the action before 60 seconds, he was marked with an N (No). The time of completion for each activity was recorded for the first and the second days, and the difference in time between these times and the percentage of reduction were calculated.

For activities 1, 2 and 5, a reduction on the time used to finish the action of 70 up to 90% was observed. Looking at these results, it can be observed how easy it was for users the adaptation to a new virtual environment as well as to the use of the Showbuilding tool. This fact also denotes that this tool is well designed from the point of view of usability.

For activities 3 and 4 only a reduction on the time used of 7-8 % was registered. These results were the consequence of the fact that users, having learned about the use of the specific tool for changing materials, both wall and floor materials, spent more time thinking about the best material option or even about different available choices for materials.



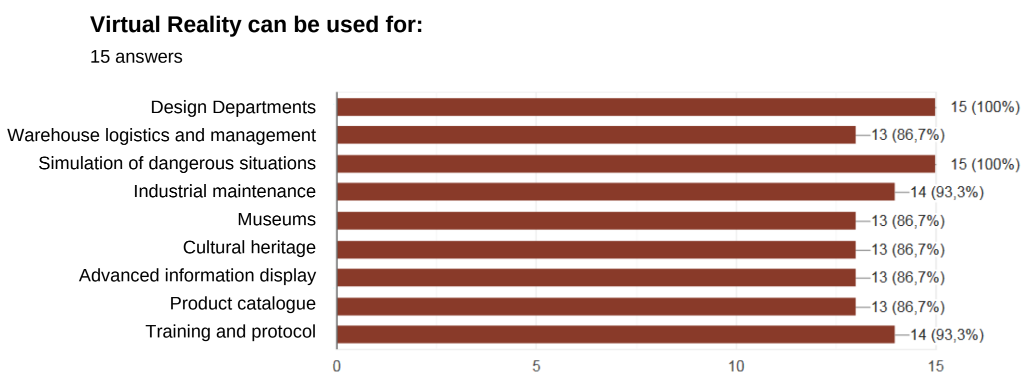


Fig. 5: *Users opinion about the uses of extended reality, before (above) and after (below) the project sessions*

From the conducted surveys, a very interesting finding stands out in reference to the perception that users have about the potential uses of virtual reality in the field of architecture and construction. Thus, to the question of what could be the main uses of extended reality (virtual and augmented) in the building sector, the users not paid attention at first time on key uses as maintenance activities or product catalogues, to give a couple of examples. After a theoretical lecture and the activities sessions, the degree of perception and knowledge about the potential of these technologies increased as it can be seen in Figure 5.

Activity 1	**To modify the natural lighting, morning, afternoon and night**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Average (seconds)**	**%**
	Help at 40 seconds			Y										Y	Y			
	Activity finished before 60 seconds			N										N	N			
	Duration first day (seconds)	31	60	76	35	50	24	18	22	32	19	24	50	78	80	9	41	
	Duration second day (seconds)	10	6	15	8	13	19	9	10	15	11	11	15	17		8	12	
	Reduction (seconds)	21	54	61	28	38	5	9	12	17	8	13	35	61		1	**29**	**71**
Activity 2	**To move the dining room**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Average (seconds)**	**%**
	Help at 40 seconds												Y					
	Activity finished before 60 seconds												N					
	Duration first day (seconds)	30	17	28	38	30	15	22	10	15	8	18	77	35	4	2	23	
	Duration second day (seconds)	3	7	10	5	7	13	7	4	11	7	2	5	5		3	6	
	Reduction (seconds)	27	10	18	33	23	2	15	6	4	1	17	73	30		-1	**17**	**73**
Activity 3	**To modify the floor material**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Average (seconds)**	**%**
	Help at 40 seconds																	
	Activity finished before 60 seconds																	
	Duration first day (seconds)	46	11	8	58	23	13	13	16	13	47	17	11	45	55	2	25	
	Duration second day (seconds)	15	23	14	19	14	8	13	7	65	71	19	37	20		2	23	
	Reduction (seconds)	31	-12	-6	39	9	5	0	9	-52	-24	-2	-26	25		0	**2**	**7**
Activity 4	**To modify the wall material**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Average (seconds)**	**%**
	Help at 40 seconds																	
	Activity finished before 60 seconds																	
	Duration first day (seconds)	20	30	12	10	18	13	12	13	23	24	6	10	22	12	13	16	
	Duration second day (seconds)	7	13	27	19	7	20	16	10	4	9	48	3	18		3	15	
	Reduction (seconds)	13	17	-15	-9	11	-7	-4	3	19	15	-42	7	4		10	**1**	**8**
Activity 5	**To move to the entrance of the house**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**Average (seconds)**	**%**
	Help at 40 seconds	Y	Y			Y			Y	Y	Y		Y					
	Activity finished before 60 seconds	N	N			N			N	N			N					
	Duration first day (seconds)	90	175	39	30	83	38	34	117	123	59	35	63	30	30	2	63	
	Duration second day (seconds)	5	8	12	2	8	7	3	9	8	9	5		7		3	7	
	Reduction (seconds)	85	167	27	28	75	31	31	108	115	50	30		23		-1	**57**	**90**

Table 1: *Summary of results from the five activities conducted in two different times*

It is important to note that when students entered inside their models, many of them realized that they could not stand on the second floor of the building. This underscores the importance of being able to virtually visit the model in the previous design stages to check the volumetric design. Moreover, one can also realize about the power of VR as a tool for learning geometry.

The obtained results in this paper are in agreement with those published results by the abovementioned authors, where the interaction between the users and the 3D environment resulted in higher motivation and engagement with the learning process, as well as a better visualization of the architectural designs and construction processes [6, 7].

4. CONCLUSIONS

In this study, a series of immersive activities were performed in the Degree in Technical Architecture and Building at the University of Lleida with a double purpose. First, to assess the potential of VR as teaching-learning tool in the fields of architecture and construction. Second, to test specific tools for the architectural field that are currently being developed by INVELON Technologies Company with the purpose of allow interaction between users and virtual building, with the aim of improve and customize designs.

The results show interesting conclusions that can be summarized as follow:

- The teaching-learning capacity of using virtual reality tools is very high, which gives these technologies great potential for use both in education and in the professional field.
- In just three sessions (immersions), users were able to reduce the necessary time to execute the proposed actions in values between 70 and 90%.
- There is still a great lack of knowledge about the current and future potential uses of these technologies.

In future actions, the aim will be to work with larger samples, with more complex activities, and extending users to the fields of industrial engineering.

5. ACKNOWLEDGEMENTS

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