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Abstract	The increasing graphic quality and ease of use of the current generation of videogame technology compels educators to rethink how architecture students learn. This paper presents the results of an educational experience with architecture students that explored the suitability of virtual environments as an educational tool. Students explored the simulated environment of an architectural proposal and filled a survey asking whether the experience had made them reason about some fundamental qualities of space. The results revealed that the virtual environment was capable of making students reflect on the functional, formal or material qualities of architectural spaces, suggesting a new education avenue using gamification or serious games strategies.

Keywords (separated by '-')	Architecture - Education - Gamification - Unreal engine - Virtual environments

Simulated Environments in Architecture Education. Improving the Student Motivation

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1 Introduction

In the field of architecture, the suitability of the designs (buildings or urban environments) must be assessed before they are built, in a process that can span years. Representation technologies are used throughout the architectural design process to bring ideas into reality, allowing communication between designers, clients, contractors and collaborators [1]. Architecture students must learn to be proficient in these representation technologies throughout their studies, and must reach the point where drawing and representation blend together, and drawing becomes thinking [2]. Therefore, it is paramount that students become skillful in multiple representation technologies, and that they are capable of incorporating the latest technologies into their design process in order to better communicate their proposals, and to facilitate the critical reasoning on the spaces they conceive.

Á. Rocha et al. (eds.), *Recent Advances in Information Systems and Technologies*,
Advances in Intelligent Systems and Computing 571, DOI 10.1007/978-3-319-56541-5_24

The project presented in this article consists of an investigation at the intersection between computer sciences, the education of future architects and multimedia engineers, and the urban policies in future cities [3, 4]. One of the most innovative aspects is the incorporation of game strategies in a virtual and collaborative urban environment, aimed at improving the initial proposal. This approach incorporates the architecture students into the project in an active way, clearly enhancing their spatial and urban competences.

2 Literature Review

2.1 Games and Architectural Representation

Games are created by designers/teams of developers, and are consumed by players [5]. They are purchased, used, and eventually cast away like most other consumable goods [6]. The difference between games and other entertainment products (such as books, music, movies and plays) is that their consumption is relatively unpredictable. The string of events that occur during gameplay and the outcome of those events are unknown at the time the product is finished [7].

The gamification in classes helps to improve the connection between the material and the student. It offers the opportunity to reflect on a topic in depth and allows positive changes in behavior [8]. In this approach, learning through gaming is achieved by aligning the game mechanics with Bloom's taxonomy of learning [9], allowing learning to be classified into three domains [10]:

- Cognitive, which is taught in traditional education and implies understanding and synthesis of knowledge.
- Affective (involving emotions), which reflects the attitude toward a situation.
- Psychomotor (the physical), which is activated by requiring a union of mental and physical activity.

To encourage the use of games in learning beyond simulations and puzzles, it is essential to develop a better understanding of the tasks, activities, skills and operations that different game types can offer, and examine how these might correspond to the desired learning outcomes [11].

Using game engines for representation is beginning to gain traction in the architectural field, which until recently had been a stronghold of 3D rendering, generally producing static images and occasionally videos (as a succession of 3D renderings with scripted camera movements). With the game industry improvements in real-time hardware-assisted 3D rendering, the quality provided by game engines is quickly approaching the levels of realism of traditional offline rendering engines, while providing additional features, at a fraction of the cost.

Furthermore, real-time rendering offers one benefit that no other technology can provide: immersion, which allows the user to freely navigate the environment and interact with some of its elements (e.g. doors, lighting, avatars); this sense of presence can be enhanced when using positional audio cues and/or virtual reality (VR) head-mounted displays.

2.2 Videogames in Education

Historically, in civil and building engineering education, visualization and understanding of 3D space was typically accomplished via the classical view (physical models and drawings), in front of 3D models and using virtual specifications. This approach is changing due to a generational change and the continuous improvement and development of technology. The new systems based on VR/AR (Virtual and Augmented Reality), Geo-Referencing, and learning gamification will gradually reduce the control imposed on the designed tasks and scheduled presentations.

The current generations of students are “digital natives” [12], and Information and Communication Technologies (ICTs) are an integral part of their life. Smartphone and computer use among Spanish digital natives is very high, as well as digital communications, with over 95% of Spaniards under 35 using the Internet for personal reasons [13]. Digital natives enjoy playing videogames, and as a result spend less time consuming other audiovisual content [14]. Although players have different preferences [15], the use of game mechanics in non-game situations, or “gamification” [16] can be a powerful educational tool [17], stimulating motivation [18] through engaging elements of game-playing, although some authors [19] attribute the observed benefits not to game mechanics themselves, but to framing.

Gamification should not be confused with “serious games” [20], which use simulations [21] to provide a realistic context for training purposes. While gamification and serious games apply to game-playing in general, they are both frequently discussed in the context of videogames or videogame technology.

3 The Project: ArchGAME4CITY

The project and initial case study presented are framed within a university environment. The main hypothesis is based on demonstrating that the implementation of virtual gamification strategies in the urban design field generate an improvement in the student’s spatial comprehension and motivation, not only for the contents, but also for the use of virtual technology.

This paper discusses an educational experience developed in an elective course in the Barcelona School of Architecture, introducing new technologies to architecture students: photo scanning, augmented reality (AR) on mobile devices, 3D printing and real-time rendering using videogame technology. In this course, the use of the game development platform Unreal Engine 4 (UE4) was introduced for the first time, being selected because of its cost (free for architectural visualization), graphics quality and ease of use of its node-based scripting.

The authors wanted to explore the suitability of videogame technology in architectural education, following their experiences using AR in formal education in the architecture degree [22], and on informal learning in public participation processes [23]. This course introduced different emerging technologies in the field of architecture representation. The section about real-time rendering discussed in this paper was distributed into 9 sessions following the sections about photo scanning and augmented reality, and before the section on 3D printing.

The surveys were conducted electronically using Google Forms, which allowed the students to fill them easily using any internet-connected device with a web browser at any time, an important advantage because their studies did not leave them much free time to devote to responding anonymous non-compulsory surveys. The pre-course survey was filled by 6 participants (23%) and the post-course survey by 10 (38%) and their responses were automatically collected into a Google Drive spreadsheet for later analysis. The surveys were visually divided into blocks of related questions according to their theme (questions specific to architecture, the development of the course, the example demo, motivation after the course, participant profile and satisfaction with the Unreal Engine platform). Each block had between 2 and 5 questions.

The pre-course survey questions focused on the example executable used in the first session of the course, and the post-course survey on the development of the course. Both surveys were in Spanish language. The majority of the responses used a Likert scale [24], either diverging between two opposite poles (positive, neutral and negative), or ordered sequentially. The possible responses were presented in a grid, with the shared scale ordered from low (left) to high (right) on the vertical columns and each aspect of the question in a different row. The order of the rows was automatically randomized in each survey to eliminate response order biases.

4 Results

The demo students played during the introductory class focused on visual aspects related to architecture visualization instead of gameplay: there were no competitive elements or any possibility to be harmed; the avatar walked instead of running, and materials and lighting were realistic instead of stylized. The virtual environment recreated a lot besides the building where they studied (Fig. 1).

Fig. 1. Picture of the actual building next to the barcelona school of architecture (left) and virtual environment with the renovation proposal (right).

The objectives of this demo were twofold:

- Showcase the features of the game engine applied to realistic architectural visualization, in order to encourage students to learn to use the tool after seeing its advantages.
- Explore the possibilities of using virtual environments as an educational tool in architectural education to reason about the qualities of architectural spaces.

Students were asked about the perceived usefulness of 9 different architectural representation techniques, ranging from the more traditional to the most widely used in their studies (Fig. 2).

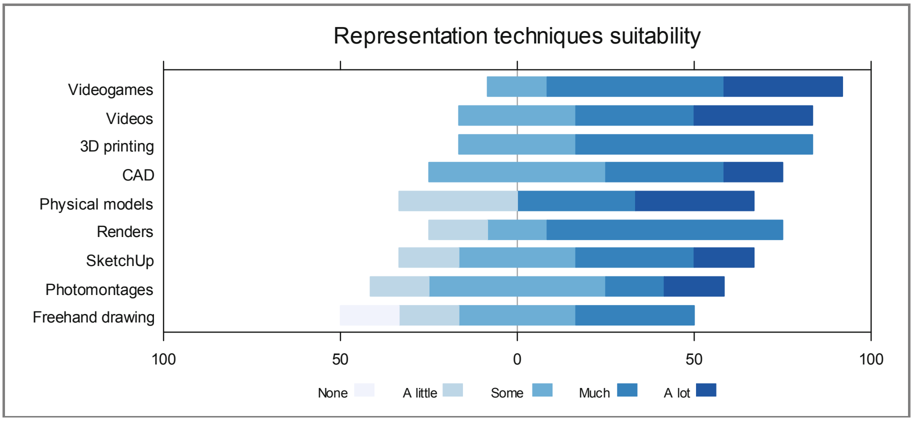

Fig. 2. Perceived usefulness of different representation techniques used in architecture.

To explore the suitability of virtual environments as educational tools to promote critical reasoning among architecture students, the participants were asked whether their experience navigating the simulation had made them reflect on several fundamental qualities of architectural design.

The results showed that, in most of the key aspects they were asked about, the interactive first person virtual experience of the environment had a positive influence on their appreciation of the qualities of the simulated space (Fig. 3 Capacity of virtual environments to promote critical reasoning on fundamental architectural education aspects).

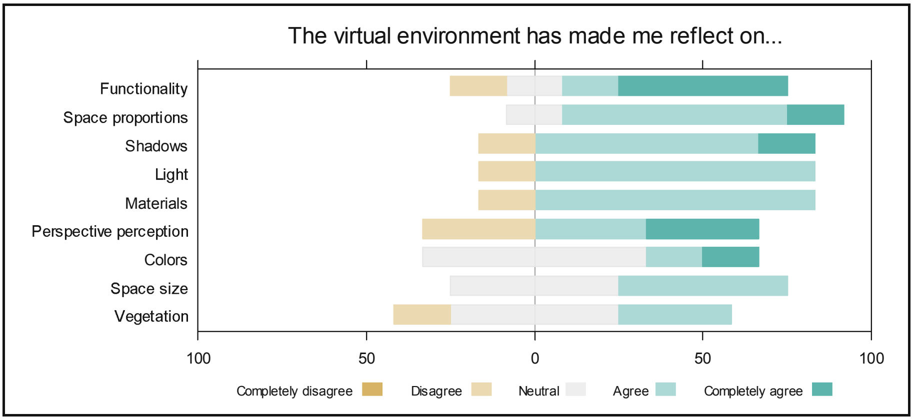

Fig. 3. Capacity of virtual environments to promote critical reasoning on fundamental architectural education aspects.

However, a small number of participants did not report any advantage in some of the aspects (brown segments in the graph), a fact that will be researched in further investigations.

In the post-course survey, two questions were designed to indirectly measure student motivation at the end of the course, asking their interest in developing their newly acquired skills and to apply them professionally (Fig. 4 Interest in further developing skills acquired in the course, specific skills (above) and professionally (below).

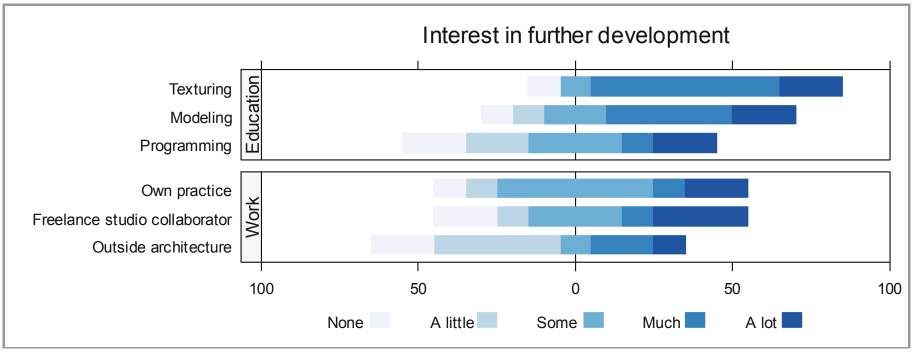

Fig. 4. Interest in further developing skills acquired in the course, specific skills (above) and professionally (below).

When asked about their interest in continuing their education on basic skills introduced in the course (Fig. 4), they manifested very high interest in developing texturing and modeling, while their interest in programming was more lukewarm, with only about half of them being highly interested. Their response was in line with the results of the questions about what aspects should emphasized in the next edition of the course, where texturing and modeling were highly rated, while interactivity and programming were not. Apparently, while the participants clearly manifested a high interest in the creative aspects of the technology, in the more technical skills appeared to two profiles: one very interested in the programming side of the technology and another one not interested at all.

5 Discussion and Conclusions

The main objective of the course was to introduce architecture students to videogame engines as an emerging technology in the field of architectural visualization, taking advantage of the availability of affordable (zero or low-cost) solutions that offer very high quality results and –considering their complexity–, relatively friendly user interfaces.

The surveys showed that the students were very interested in the technology before taking the course, and remained interested when they finished, a remarkable fact considering that the course was demanding in its difficulty and required a considerable time dedication. This motivation can be explained from a practical point of view because videogame technology has the potential to replace the current non-real-time rendering solutions with a cheaper alternative, providing immediate feedback when placing 3D elements, defining materials or lighting the scene, while offering extra features like the capacity of navigating and interacting with the virtual environment, and other features like VR which will soon be supported on mobile platforms.

In addition to validating videogame technology as a representation technique, a secondary objective of the experience was to explore the suitability of virtual environments as a tool to promote critical thinking in architecture students.

The survey conducted after exploring the virtual environment showed promising results, supporting the hypothesis that virtual environments are capable of making students reflect about the functional, formal or material qualities of architectural spaces. These findings open a new avenue of educational research using serious games, where students could virtually experience different cultural and historical contexts, or be placed in a specific space, but with different roles (e.g. wheelchair-using person, child) or situations (e.g. crowded spaces, day/night cycle, weather and seasonal changes). These virtual environments should complement, and not replace, other means architectural education, such as traveling or open discussion of ideas. Furthermore, tracking the behavior in these virtual environments could be a valuable architectural research tool to conduct controlled experiments.

Tracking individual persons in public spaces is challenging; although it is possible to accurately track their movement using RFID or other technologies [25], it is technically difficult, and it raises privacy concerns when gathering data in public spaces. In areas such as economics, synthetic experiments are performed to model real situations, even though in some cases participants do not understand the rules fully [26].

The next phase of the development will include the capacity of tracking (with their consent) the users' behavior in virtual space (position and gaze along time), which will allow the application to be used as a research tool [27] to conduct controlled experiments. Also, we will implement a mixed method approach to improve the assessment methodology. This model is based on a pragmatic paradigm that contemplates the possibility of combining quantitative and qualitative methods to achieve complementary results [28]. The quantitative approach will be based on ISO 9241-11, previously used in other educational cases [4, 29], which provides usability assessment guidelines of efficiency and user satisfaction. The qualitative approach will be post-visit interviews with a representative sample of the students involved in the project, who will share their experience with the appliance of this new technology into the visit. For this final stage, Bipolar Laddering Assessment (BLA) will be used, a technique also previously validated in other educational experiments [30].

Acknowledgments. This research was supported by the programs BIA2016-77464-C2-1-R of the National Plan for Scientific Research, Development and Technological Innovation 2013-2016, Government of Spain, titled "Gamificación para la enseñanza del diseño urbano y la integración en ella de la participación ciudadana (ArchGAME4CITY)" and BIA2016-77464-C2-2-R of the National Plan for Scientific Research, Development and Technological Innovation 2013-2016, Government of Spain, titled "Diseño Gamificado de visualización 3D con sistemas de realidad virtual para el estudio de la mejora de competencias motivacionales, sociales y espaciales del usuario (EduGAME4CITY)".

References

1. Horne, M., Thompson, E.M.: The role of virtual reality in built environment education. J. Educ. Built Environ. **3**(1), 5–24 (2008)
2. Suwa, M., Tversky, B.: What do architects and students perceive in their design sketches? a protocol analysis. De. Stud. **18**(4), 385–403 (1997)
3. Orland, K.: Twitch plays everything: how livestreaming is changing game design. http://arstechnica.com/gaming/2015/10/twitch-plays-everything-how-livestreaming-is-changing-game-design/
4. Fonseca, D., Redondo, E., Valls, F., Villagrasa, S.: Technological adaptation of the student to the educational density of the course. a case study: 3D architectural visualization. Comput. Hum. Behav. (2016)
5. Villagrasa, S., Fonseca, D., Durán, J.: Teaching case: applying gamification techniques and virtual reality for learning building engineering 3D arts. In: Proceedings of the Second International Conference on Technological Ecosystems for Enhancing Multiculturality, pp. 171–177. ACM, October 2014
6. Institute of Play (2013). http://www.instituteofplay.org/work/projects/quest-schools/quest-to-learn/
7. Manrique, V.: Epic win blog: the 35 gamification mechanics toolkit v2.0 (2013). http://www.epicwinblog.net/2013/10/the-35-gamification-mechanics-toolkit.html
8. Kapp, K.M.: The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education. Wiley, Hoboken (2012)
9. Zichermann, G., Cunningham, C.: Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps. O'Reilly Media Inc, Newton (2011)
10. Bloom, B.S.: Thought processes in lectures and discussions. J. Gen. Educ. **7**, 160–169 (1953)
11. Cronk, M.: Using gamification to increase student engagement and participation in class discussion. In: Amiel, T., Wilson, B. (Eds.) Proceedings of World Conference on Educational Multimedia. Hypermedia and Telecommunications, pp. 311–315 (2012)
12. Bennett, S., Maton, K., Kervin, L.: The, "digital natives" debate: a critical review of the evidence. Brit. J. Educ. Technol. **39**(5), 775–786 (2008)
13. TNS Infratest Germany: Data from the Global Connected Consumer Survey (CCS) Global Device Usage and Internet Stats. Accessed 28 Sept 2016, 10 June 2015. https://www.google.com/publicdata/explore?ds=dg8d1eetcqsb1_&hl=en&dl=en
14. Entertainment Software Association. 2015 Essential Facts About the Computer and Video Game Industry (p. 20). Entertainment Software Association (2015). www.theesa.com/wp-content/uploads/2015/04/ESA-Essential-Facts-2015.pdf
15. Yee, N., Ducheneaut, N., Nelson, L.: Online gaming motivations scale: development and validation. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, New York, NY, USA, pp. 2803–2806. ACM (2012)
16. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: defining "gamification." In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, New York, USA, pp. 9–15. ACM (2011)
17. Holbert, N.R., Wilensky, U.: Constructible authentic representations: designing video games that enable players to utilize knowledge developed in-game to reason about science. Technol. Knowl. Learn. **19**(1–2), 53–79 (2014)
18. Iosup, A., Epema, D. An experience report on using gamification in technical higher education. In: Proceedings of the 45th ACM Technical Symposium on Computer Science Education, New York, NY, USA, pp. 27–32. ACM (2014)

19. Lieberoth, A.: Shallow gamification: testing psychological effects of framing an activity as a game. Games Cult. **10**(3), 229–248 (2015)
20. Davidson, D. (Ed.): Beyond Fun: Serious Games and Media. Pittsburgh (PA): ulu.com (2010). http://press.etc.cmu.edu/files/BeyondFun-DrewDavidson-etal-web.pdf
21. Aldrich, C.: Simulations and the Future of Learning: An Innovative (and Perhaps Revolutionary) Approach to e-Learning, 1st edn. Pfeiffer, San Francisco (2003)
22. Fonseca, D., Martí, N., Redondo, E., Navarro, I., Sánchez, A.: Relationship between student profile, tool use, participation, and academic performance with the use of augmented Reality technology for visualized architecture models. Comput. Hum. Behav. **31**, 434–445 (2014)
23. Fonseca, D., Valls, F., Redondo, E., Villagrasa, S.: Informal interactions in 3D education: Citizenship participation and assessment of virtual urban proposals. Comput. Hum. Behav. **55**, 504–518 (2016)
24. Likert, R.: A technique for the measurement of attitudes. Archives of Psychology **22**(140), 55 (1932)
25. Kravets, D.: How the NFL—not the NSA—is impacting data gathering well beyond the gridiron. http://arstechnica.com/tech-policy/2015/09/the-nfl-is-reshaping-the-surveillance-society-xbox-one-experience-and-gambling/
26. Burton-Chellew, M.N., Mouden, C.E., West, S.A.: Conditional cooperation and confusion in public-goods experiments. PNAS **113**, 1291–1296 (2016)
27. Kuliga, S.F., Thrash, T., Dalton, R.C., Hölscher, C.: Virtual reality as an empirical research tool — exploring user experience in a real building and a corresponding virtual model. Comput. Environ. Urban Syst. **54**, 363–375 (2015)
28. Fonseca, D., Redondo, E., Villagrasa, S.: Mixed-methods research: a new approach to evaluating the motivation and satisfaction of university students using advanced visual technologies. Univ. Access Inf. Soc. **14**(3), 311–332 (2015)
29. Villagrasa, S., Fonseca, D., Durán, J.: Teaching case: applying gamification techniques and virtual reality for learning building engineering 3D arts. In: Proceedings of the Second International Conference on Technological Ecosystems for Enhancing Multiculturality, pp. 171–177. ACM, October 2014
30. Redondo, E., Fonseca, D., Valls, F., Olivares, A.: Enseñanza basada en dispositivos móviles. Nuevos retos en la docencia de la representación arquitectónica. Caso de estudio: Los Tianguis de Tonalá, Jalisco, México. EGA Revista de expresión gráfica arquitectónica **21**(27), 64–73 (2016)

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