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Enhanced Learning Technologies in 3D Modelling. Learning and Gamification Qualitative Assessment

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Abstract

Enhanced Learning Technologies (TEL), including augmented and immersive virtual reality environments, achieve a new way of assessing the subjects of 3D modelling. In the case of Multimedia or Architecture studies, these options allow professionals and students to explain their proposal more fully to the final users. In the last years, we have developed some projects based on Project Based Learning (PBL) and Scenario Centered Curriculum (SCC), where the students propose, design, convey, validate, and build a civil projects using new technologies that help in the assessment process. The new approach is to use gamification techniques and game engines in order to assess planned tasks in which students can demonstrate the skills they developed in the scenarios. This whole process is performed using gamification techniques to embed the assessment of the 3D models with the objective of improving student learning. This study evaluates the learning effectiveness and engagement appeal of a gamified learning activity, as well as virtual reality technology targeted at learning 3D arts for Building Engineering. The use of gamification in 3D learning has demonstrated its usefulness with outcomes comparable to the average academic results historically achieved in this subject, and the results obtained indicate that the students should not modify the enhancements of methods for presenting architectural projects in the redesign process because of the positive assessment.

Keywords

Gamification, Project based learning, Scenario centered curriculum, Motivation, Engagement, Virtual reality, Building and architecture teaching

Introduction

We can define that engagement is the main objective in applying gamification in an educational setting as our first hypothesis [1,2]. Although the gamification technique is not truly an academic methodology, rather than turning the classes into a game, the aim is to enhance the students' learning process [3-5]. Student engagement can be defined as a "student's cognitive investment in active participation in and emotional commitment to their learning" [6].

In recent years, educational gaming has been progressively perceived as an effective tool for improving teaching-learning activities in higher education [7]. Gamification focuses on applying game mechanics to any project, idea or situation [8]. In our case, the goal was to implement game mechanics to make learning [9], and instruction more fun [10], which would, in turn, allow longer retention of the material among the students [11]. According to Sebastian Deterging [12], "Informal umbrella term for use of videogame elements in non-gaming systems to improve UX and user engagement can be used for educational problems: Student motivation and engagement". To apply game mechanics and achieve a level of fun, we must first follow some rules. For example, rewards can be delivered through the creation of leaderboards, badges, and loyalty programs that encourage

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students to have fun and perform a learning activity as desired by the teacher. In addition, we need some means of measuring qualification and achieving motivation because motivated students are more effective in learning. They need the feeling of accomplishment and success of striving against a challenge and overcoming a difficulty to push them forward to the next level.

In architecture and related studies, such as engineering construction and civil engineering, the process of project design and creation is usually complex. Often, the sketch of a design begins with 2D drawings, which lead to a 3D model, thus helping to validate each space and building component that is created. Although 3D models have many functions, perhaps the most fundamental stems from the effectiveness with which a model can communicate the design, helping both the student and the professional appreciate its complexity. In this communication process, the outcome is usually a set of photorealistic renders from different perspectives, with occasional animation tours. However, this system is not interactive. The final viewer of the project is not given options to view the three-dimensional model more closely, which can create a feeling of misinformation and a general lack of motivation in the final exposition. As a second hypothesis, we can define that the use of technological innovations (that involve gamification techniques), achieve higher motivation and to increase satisfaction among students [13]. In order to assess our hypothesis, we must to use and compare new technologies for a better way of presenting and learning 3D modeling involving gamification techniques.

This paper includes an overview of academic performance using gamification and visual technology and discusses how this type of technologies can improve students' 3D skills and engagement. The main features, and results of this qualitative approach, applied in the educational framework, are described in the Evaluation section.

Games and Gamification

Games are created by designers/teams of developers and are consumed by players. They are purchased, used and eventually cast away like most other consumable goods. 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. The MDA framework formalizes the consumption of games by breaking them into their distinct components [14], i.e., Rules = > System = > Fun, and establishing their design counterparts:

- Mechanics describes the components of the game at the level of data representation and algorithms.
- Dynamics refers to the run-time behavior of the mechanics acting on player inputs and outputs.
- Aesthetics pertains to the desirable emotional responses evoked in the player through game interaction.

Gamification in classes helps to improve the connection between the material and the student, offers the opportunity to reflect on a topic in depth and allows positive changes in behavior [1]. In this approach, learning through gamming is achieved by aligning the game mechanics with Bloom's taxonomy of learning [15], allowing learning to be classified into three domains [16].

- 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 to examine how these might correspond to the desired learning outcomes [17]. Extant studies in education/learning contexts considered the learning outcomes of gamification as mostly positive. For example, outcomes were assessed in terms of increased motivation and engagement in the learning tasks, as well as enjoyment derived from partaking in the tasks [12]. However, these studies revealed some negative outcomes that need to be addressed, such as the effects of increased competition, task evaluation difficulties, and design [18]. Product designers and marketers are leveraging this alignment in business contexts to "make them [consumers] come in, bring friends and keep coming back". The reward is often not directly related to the goal achieved but rather serves as a notification to the player and others that a level of competence has been achieved. Progress tracking is often enabled and is guided by reward systems. Similarly, progress towards an overall objective is mapped out by a sequence of intermediate goals.

Game playing is associated with trial, error, failure and eventual success through practice, experience, reflection and learning. A key objective of most games is not to prevent failure but to develop a positive relationship with it. Failure is not seen as an end but as a step in the journey to mastery. Gamified learning interventions seek to maintain a positive relationship with failure by creating rapid feedback cycles and keeping the stakes for individual learning episodes low. In many ways, the paradigm that governs current educational systems has many game-like elements. Most assessments strive for objectivity, and continuous assessment is seen as desirable. Students earn points for completing assignments correctly. These translate into comparable rewards-grades. If they perform well, students "level up" by proceeding to a more advanced course of study at the end of every academic year [19]. What distinguishes gamification most distinctly from more traditional approaches is the explicit use of competition as a motivational tool. This competitive element is a source of motivation [20]. These ranking systems serve as motivators because users see their efforts instantly recognized [21]. In education, motivation is considered a key determinant of learning. It is used to explain the attention and effort students dedicate to particular learning activities [22]. In our approach to gamifying learning, we employ common gamification design elements [23].

- Objective: Gamified activities have rules that predetermine the actions a player can or cannot take.
- Rewards: Gamified learning activities have a reward system that provides users with SAPS (Status, Access, Power and Stuff) for interacting with the game successfully.
- Quick feedback: By receiving timely feedback, the users can quickly learn how to improve at the game.
- Cycles: Incorporating competitive elements into gamified activities presents users with a challenge, while the objective outcome associated with the games allows for ranking of users.

Intrinsic motivation is another key element because it involves learners that are interested in what they learn and in the learning process itself. In contrast, individuals possessing extrinsic motivation engage in learning because it is a means to an end. Thus, their approach is relatively disassociated from the content and subject of learning [24]. Intrinsic motivation, conceptually, it is closely associated with cognitive behavioral theories and the work of Piaget. The author posits that, when individuals experience discrepancy between their experienced knowledge of the world and their private, internally held knowledge, they are driven to eliminate this discrepancy [25]. On the other hand, extrinsic motivation is associated with B. F. Skinner's behavioral theories of human learning and focuses on the provision of rewards to direct and control learning [26].

The division of motivation into intrinsic and extrinsic is further refined in extant literature. Turning first to intrinsic motivation, it is divided into a tripartite taxonomy. This division is based on the nature of the internalized utility of the behavior. Intrinsic motivation to know is the construct best known in the educational arena. It involves the desire to perform a learning activity for the pleasure one experiences while learning (i.e., the utility to an individual is the learning in and of itself). Intrinsic motivation towards accomplishment is the second type, involving the desire to engage in an activity for the pleasure and satisfaction experienced when accomplishing a difficult feat [27]. Finally, intrinsic motivation to experience stimulation is operative when an individual engages in an activity in order to be stimulated. Stimulation can take a range of forms and includes sensory or aesthetic pleasure, as well as emotional sensations, such as fear or excitement. The relationship among types of motivation is also important, with some authors suggesting that the provision of external rewards damages intrinsic motivation, whereas others indicate that there is no evidence to support this claim [28,29].

Prompting and mediating positive learning behaviors is seen as the key advantage of gamification. However, learning motivation differs among individuals. Some learn for pleasure or to satisfy curiosity, whereas others learn to obtain rewards (e.g., a high-status job and/or financial rewards). Student motivation is an important factor in their reaction to learning activities. While some students may be motivated by having their learning gamified, this approach may demotivate others. Even if gamified learning impacts individuals differently, this fact does not necessarily deny its utility. Rather, gamified learning interventions can be included as part of a range of learning interventions. However, these interventions must be chosen in a manner that ensures no type of learner is systematically disadvantaged. For example, it is argued that common forms of academic assessment, such as essays and reflective pieces, favor learners with relatively high intrinsic motivation. A key research question raised in the pertinent literature is how individuals with different motivations for learning are impacted by gamified learning activities. A game is an activity related to the resolution of a problem, following an approach based on a clearly playful attitude. Continuing with some of the lectures by Jesse Schell [30], we posit that gamified learning requires a very well-implemented background story with "complex" goals, along with a set of rather "simple" (Usable/Playable) rules.

We should not forget that the audience of any "game" has a transcendent interest. Thus, the "story" should orbit around the four axes of Game Design. This is the definition of the Aesthetic Criteria, which require creating a set of rules or mechanics for the game, a good and dense history, and a good technological approach. The considerations in terms of the game space include the Objects (enigmas and challenges that relate to inventory Player

Characters), the actions to undertake (as in conversational Adventure graphs, these enable the relationship between objects and the game space), pre-defined rules (same for all players/students), and a proper balance between dexterity and luck. One of the most important concepts to take into account is the flow. In this context, flow is defined as the state in which we find ourselves when we are focused on a task and nothing can distract us from it. A game, a movie, a book, a concert or any kind of pleasurable and engaging experience should have a good flow, and we can be so immersed in it to the point that we lose our sense of time and space. The flow should not be linear but should take the form of a rocking curve. In this way, the user is allowed a break after a period of time in which he/she experienced intense action or emotion.

Technology Enhanced Learning (TEL) & Gamification

The TEL field of research has been profoundly involved in the development and application of collaboration applications. Computers and software tools play diverse roles at different times along the life cycle. The most common life cycle consists of four different phases: design, implementation, approval and final assessment. Essentially, TEL seeks to improve students' learning experience by:

- Supporting student engagement, satisfaction and retention.
- Helping to produce enterprising graduates with the required and defined skills.
- Encouraging inspirational and innovative teaching.
- Personalized learning that promotes reflection.
- Delivering and supporting CPD and internationalization.

Focusing on Gamifying Learning Experiences (GLE) and Game Based Learning (GBL) concepts enabled us to define a set of technologies based on game strategies that allow easier design and generate self-learning activities, tracking exercises and self-assessment. Due to the constant monitoring and evaluation of these incorporated learning methods (e.g, questionnaires, delivery system practices, and competitions), the teacher can ubiquitously validate the progress of each student. Another important factor that determines the use of GBL and GLE is the ease of adaptation and integration in Virtual Learning Environments (VLE). This approach promotes greater motivation and healthy competition among students while allowing teachers to evaluate the content adaptation to multiple representation formats, along with monitoring the students' progress. The use of teaching strategies based on games has been shown to increase student motivation. In addition, gamification is positioning itself as a new generation of assessment technologies, facilitating aligned and embedded assessment using virtual scenarios in which students can demonstrate their skills. In this way, it is possible to improve both general and specific skills in both formal and informal educational environments [31]. Learning to collaborate and mastering connections through technology is an essential skill and capability that future societies will expect from citizens [32].

Even though those of us in higher education would like to think that students understand the goal of finishing a degree or passing a course. Hence, if education is a game and students enter it without understanding the goal, they are bound to misunderstand the way the game works, as well as the methods they should use to win. If the goal is to earn a higher salary after graduation, the game play will likely focus on courses that will yield the highest effects on the curriculum vitae. In that case, success would simply be passing courses, rather than learning the content and acquiring knowledge. A quality education and an entertaining experience are the same. True intellectual challenge is exhilarating. Lifelong learners become so because they find learning fun [33-35]. Changing the fundamental nature of higher education is a daunting task, but there are small steps we can take. Below are three ideas for faculty and some example applications of each [36,37].

- Make goals clear and explain how the course, major, or degree prepares learners to achieve those goals. Ensure that students fully appreciate these goals and want to achieve them.
- Dedicate as much time in class to the syllabus covering the importance of the learning goals as is spent explaining the grading system of the class.
- When writing assignment descriptions, include a "How you can use this in the future" section.
- Make progress transparent to each learner. Grades and assignment completion are not the only ways to measure progress toward achieving goals.
- Give students a way to track their progress on each learning goal of the class. An online checklist that students fill out on their own can help them stay on track.
- Create commodities for desired behavior.
- Add peer voting to class activities, such as discussions and online forums. Allowing students to identify the contributions that they see as valuable will highlight good models for other students to follow and will

provide positive feedback to the contributing student.

Other key concepts implicit in gamifying education include the need to pay attention to the structure and the content from the gamified activity. Structural gamification is the application of game elements to propel learners thorough content with no alteration or changes to the content [38]. In other words, while the structure around the content becomes game-like, the content is unaffected. The primary focus behind this type of gamification is to motivate learners to go through the content and to engage them in the process of learning. The structure comprises Rules, Reward structure, Leaderboards, Points, Currency, and Badges as the core elements. Content gamification is the application of game elements, game mechanics and game thinking to alter content to make it more game-like [39]. For example, adding story elements to a compliance course or starting a course with a challenge instead of a list of objectives are both methods of content gamification. Here, Story, Challenge, Curiosity, Character, Interactivity, Feedback, and Freedom to Fail are the key components.

Case Study: Drawing Techniques Subject

Objectives

To exemplify the methodology explained, we have designed a case study applied in a Building Engineering and Architecture Degrees subjects. A qualitative study evaluating the motivation, satisfaction and academic performance of degree students is presented. The methodology is qualitative (using the Bipolar Laddering [40] and combines the use of gamification with technology suitable for 3D arts. The working hypothesis to be confirmed is whether students who learn 3D techniques via gamification techniques obtain better academic results because they are more motivated and satisfied than those taught under the classic working system.

Participants

The sample was composed by the students of "Drawing techniques 2" a six-ECTS credit course, (European Credit Transfer System) that is taught during the second semester of the academic year. The sample was defined by 20 students included 12 males (mean age of 19.29 years with a standard deviation of 0.85) and 8 females (mean age of 20.35 years and standard deviation of 0.74). Following previous recommendations [14], in order to work with the BLA method is enough with this sample, because for the characterization of educational issues using this qualitative assessment we can work with a minimum of 6-8 samples.

Procedures

For multimedia/building engineering, the following 3D technologies were selected for work system integration: Unity, Sketchfab, and Oculus Rift VR. Unity is a game engine that allows the user to develop any kind of game with relative ease. This engine enables the creation of virtual worlds of high quality and realism that can later be uploaded to the web. In our case, it was used to create these worlds with the material created by the students in their projects. Once created, students can visit these worlds to examine the work of their peers. This process generates a highly interactive classroom. Moreover, the work tends to be more detailed and of higher quality because students like demonstrating their knowledge to their peers. This, when combined with Oculus Rift VR activity, generates increased the of the quality experience because the latter-as a virtual reality viewer-enables the users to view the generation of stereoscopic 3D content and facilitates the creation of first-person experiences by, for example, simulating the movement of the head. Finally, in this case study, we used Sketchfab, a web platform that allows its users to upload 3D models using WebGL for viewing from Windows, Mac, Linux, Android or iOS systems.

The aim of the course is to introduce the creation of 3D content, emphasizing modeling, texturing and lighting of 3D scenes, and basic knowledge of computer animation, which is model-driven for design and audio-visual production. The total estimated project work is about 50 hours. The group are composed of two or three students. The learning process typically takes place in groups, focusing on collaborative challenges and interaction with peers (Figure 1).

In the classroom, we have created discussions among groups, and initiate contests, allowing each group to compete for rewards. The storyline of the game that we proposed is that all the class is working on a global project for an exposition, such as a universal expo, and the goal is to design a pavilion with very few constraints. The location is a virtual island created using Unity and is compatible with Oculus Rift, allowing for a real 3D immersive virtual reality experience (Figure 2).

The evaluation system shown in Figure 2 is balanced, with a percentage of points awarded for direct representation. Throughout the course, students must earn a maximum of 10,000 points. We can divide the subject into two main groups. The first pertains to the house project, with a total weight of 70%, and the second project, the Virtual Island, carries a total weight of 30%. The assessment method applied to the first project comprises: Modelling (1000 points), texturing (1000 points), rendering and lighting (1000 points) and panel (4000 points). This results in a maximum score of 7000 points, i.e., 70% of the total value that, when mapped to grades from 1 to 10, would correspond to a 7. The greater weight

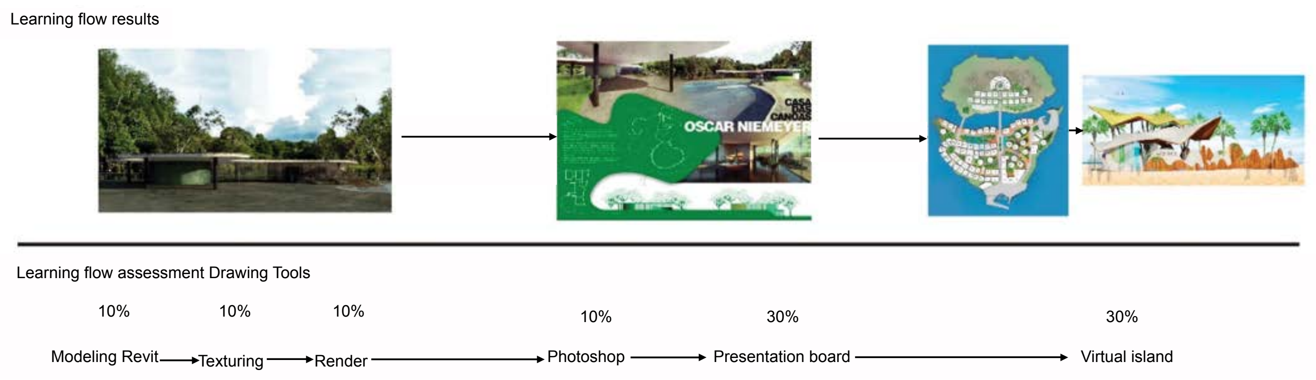

Figure 1: Learning objectives and assessment weights.

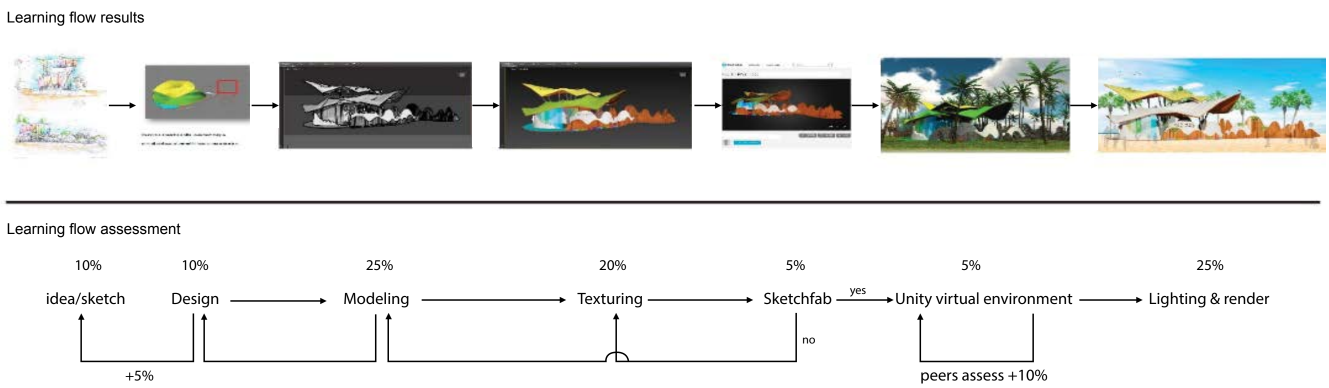

Figure 2: Methodology for embedding the assessment of the virtual island.

Figure 3: Left: Masterplan; Right: Virtual Reality of the island with the pavilions of the students.

of the evaluation means that the student is in the phase dedicated to learning to use the tools, and the time devoted to their use is aligned to the value of the assessment. This first exercise is developed using Revit Architecture and Adobe Photoshop (Figure 1). Thus, students were required to search information, participate, and present their project before a digital architectural panel. In an intermediate stage, teachers conducted a few exercises consisting of certain recreations and modifications of one of the buildings of the faculty using Adobe Photoshop. Finally, the teachers conducted exercises regarding the consistent improvement of the rendering of 3D example models with Autodesk 3ds Max. In this phase, students had to deepen their knowledge of texturing and lighting to recreate the house for panel presentations, this time in a physical and professional format (Figure 2). For this assignment, they could be awarded maximum of 500 points for the entire process of drafting, and further 1500 for the submission and staging of the final poster, which included night and day images. Furthermore, the students vote for the name of the island during a discussion created in Schoology, which is an LMS tool that shows the points earned and the progression on a weekly basis, with the aim of personalizing the island and making it important to the students. With a gamification background, the building engineering and architecture students work with 3D tools to produce architectural models. The goal is to encourage the architecture students to collaborate and actively participate in the creation of collaboration projects from the beginning. When the project is complete, the virtual exposition is showcased, allowing the students to view their work on any platform, such as a PC, tablet, mobile phone, and new VR technologies, using Unity and Oculus Rift (Figure 3).

Data collection

Qualitative methods are commonly employed in usability studies, inspired by experimental psychology and the hypothetical-rn psychology is also applicable and valuable in the sdeductive paradigm, employing a relatively limited number of users. Nevertheless, the Socratic paradigm from postmodee studies of usability because it targets details related to the UX with high reliability and uncovers subtle information about the product or technology studied. Unlike the objective hypothetical-deductive approaches, this psychological model defends the subjective treatment of the user. Starting with the Socratic paradigm, we adopted the BLA system (Bipolar Laddering), which works on positive and negative poles to define the strengths and weaknesses of the product. Once the element is obtained, the laddering technique is applied to define the relevant product details. The characteristics obtained through laddering help to define what specific factors make an element a strength or a weakness. The next step is to polarize the elements based on two criteria:

- Positive (Px)/Negative (Nx): The students must differentiate the elements perceived as strong points of the experience that helped them improve the type of work. These elements are classified as useful, satisfactory, or simply functional aesthetic (Table 1). On the other side are the negative aspects that did not facilitate work or simply need to be modified to be satisfactory or useful (Table 2).
- Common Elements (xC): The positive and negative elements that were repeatedly mentioned by the students (common elements) are identified according to the coding scheme (Table 1 and Table 2).

Once the features mentioned by the students are identified and given values, the third step-the qualitative stage, as defined by the BLA-can commence. Here, stu-

Table 1: Positive Common (PC) elements.

	Positive Common (PC)	Av Score (Av)	Mention Index (MI)
1PC	Use of multiple edge technology	8.2	90
2PC	Learning by doing methodology	8.5	40
3PC	Gamification techniques and awards	7	40
4PC	Creativity modelling	9.3	70
5PC	Collaborative works	8.3	30
6PC	Professional portfolio	8	30
7PC	Use of virtual reality	9	90

Table 2: Negative Common (NC) elements.

	Negative Common (PC)	Av Score (Av)	Mention Index (MI)
1NC	Little time for learning 3D	5	90
2NC	Use of schoology points LMS	4	30
3NC	Lose track of contents	2	60
4NC	Group grades versus individual	5	40
5NC	Gamification: points & badges	6	30
6NC	Many retouching image tools	5	50
7NC	Use of vectorial software	5	10

Table 3: Proposed Common Improvements (CI) for both positive and negative elements.

	Description	Mention Index
1CI	Small groups	20%
2CI	Unified web portal with a better gamification	60%
3CI	Starts with more easy exercise	10%
4CI	More 3D for design or films versus videogames	10%
5CI	Beginning of the subject, clarify minimum specs	20%
6CI	More detailed grades. Rubrics for collaborative works	40%
7CI	Web Site with tutorials, and maps for find the path again	50%
8CI	Better weight. Rounded numbers. Unified web portal with a better visualization of grades	30%

dents describe and provide solutions or improvements to each of their contributions in the format of an open interview. The common elements that are mentioned more frequently (Table 3) are the most important aspects to use, improve or modify (according to their positive or negative sign). Other elements, especially those identified by a single user only, may be ignored or addressed in later stages of development.

As we have previously stated in section 4.2, this method is very useful with short samples, as has been also demonstrated previously [41]. The relation between the mention index and the average of every item, allow us to related the free answers of the students with the main ideas developed in the project as we can see in the next section.

Data analysis

These results indicate that the adaptation of the content and the processes designed for the VR Island led to outcomes comparable to the average academic results historically achieved in this subject. This approach allowed us to corroborate the qualitative data collected using BLA (Table 1 and Table 2). Although there was excess content regarding the time and the appeal of the VR system, the structure of the course was highly valued.

The individual values obtained for both indicators, positive and negative, are shown in (Table 1 and Table 2). Table 3 shows the main improvements or changes that the students proposed for both the positive and negative elements. Only the "common" aspects, i.e., those identified by at least two students, are included. Before discussing the results, it is interesting to identify the most relevant items obtained from the BLA, in terms of high rates of citation, high scores, or a combination of both. Because work is performed following an open-ended method, some of the elements above were not at the focus of the study (i.e., the evaluation of new visual techniques in the teaching field). Thus, only the elements most closely related to the motive of the study are highlighted. With respect to positive remarks, the multiple use of edge technology (MI: 90 %, Av: 8.2) and the use of virtual reality (MI: 90 %, Av: 8.2) can be highlighted. This indicates that the enhancements of methods for presenting architectural projects should not be modified in the redesign process.

Based on the positive data yielded by the BLA, the improved academic performance can be attributed to the student motivation (great scores in the positive assessment related with the negative item of "lack of time", the visualization methodology based on VR and the gamification techniques, and the enhancement technology provided by working with 3D in a collaborative way. However, there are a number of negative aspects (Table 2) and solutions proposed (Table 3) by students that have had a direct impact, including the lack of time for practical realization, VR explanations and techniques for rendering in 3D; all of them items to be improved in next iterations.

Conclusions

Those who resist gamification in education often cite its improper use of rewards as a motivator. Critics argue that relying on games can be detrimental to intrinsic motivation. Indeed, receiving a badge for a job well done is meaningless without an understanding of what specific skills the badge rewards. Thus, in our view, games cannot be used to replace pedagogy but have the potential to enhance the overall learning experience.

The use of TEL and gamification for assessment in 3D arts has demonstrated its usefulness as a system that can easily align the assessed process and increase the embedded workflow of assessment. Gamification has not only increased student motivation but has also helped integrate the evaluation process in each of the phases of the project. The phase-by-phase 3D construction process of the pavilion is a good way to learn the basics in a completely practical way. The use of gamification in the evaluation process has helped to create a better project and has provided opportunities for self-evaluation. A well-aligned process helps students learn while developing the project itself. The final project results and personal interviews based on the BLA model indicate that some essential improvements could be achieved. Having the island exposed publicly in a VR using a computer or an immersive device creates competitiveness between students that designed different pavilions. Furthermore, the use of the virtual island project and gamifying the tasks with VR offers students greater motivation to complete their work (in this case, creating complex environments to be urbanized). The technology uses can be beneficial in the development of creativity, design of 3D modeling, lighting, rendering, and textures. Additionally, the use of 3D visualization on mobile devices using 3D web services, such as Cl3ever or Sketchfab, helps to produce more detailed projects that can be integrated into students' digital portfolio.

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