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SERIOUS VIDEO GAMES IN ENGINEERING EDUCATION: A SCOPING REVIEW

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Abstract

Video games have become an important element of contemporary life. The need to use them in the field of education has given rise to the appearance of serious video games, which have been specially designed to achieve objectives at different educational levels and generate spaces for educational innovation. The purpose of this work is to investigate the use of serious video games in engineering education. A scoping review was carried out on serious video games that were used or designed for this purpose. The search was done in the Scopus and Web of Science databases between 2016 and 2021. The main results show that there is a strong inclination towards serious simulation video games, and they have a good degree of educational acceptance among engineering students.

Keywords – Video games, Engineering, High education, Gamification.

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1. Introduction

For decades now, technological advances have generated changes in different aspects of life. The emergence of technologies such as the Web 2.0 have resulted in changes in teaching and learning processes, and so it is necessary to investigate the skills related to the use of digital technology for professional, social and personal use (Challinor, Marin & Tur, 2017). Among these new technologies that are changing different aspects of human life are digital or electronic games, also referred to as video games, the transcendence of which in contemporary life has favored them becoming a powerful creative industry and a growing technological trend; but above all, video games have burst onto the scene in such important areas of human activity as education (Clerici, Naef & Eckerdt, 2021; Núñez-Pacheco, Barreda-Parra, Guillén-Chávez & Aguaded, 2021).

It is necessary to point out that video games are associated with other related terms, such as in the case of gamification, game-based learning, digital learning games and serious games. Becker (2021) indicates that

there is still a great deal of confusion about the use of these terms. Gamification is a tool that consists of the use of game mechanics in non-leisure settings, such as education (Prieto-Andreu, 2020). Game-based learning has to do with the use of games in the learning process. Serious games are designed from the very beginning with this purpose in mind.

The term serious game was initially coined in 1970 by Clark Abt, who differentiated between games to have fun and games to learn; but the term became better known thanks to David Rejeski and Ben Sawyer, who promoted the "Serious Game Initiative" to establish more productive links between the video game industry and projects involving the use of games in education, health, training and public policy (Bellotti, Bert & De Gloria, 2010; Prieto & Medina, 2015).

Serious video games are associated with learning experiences and have three characteristics: knowledge transfer (educating), skill transfer (training) and attitude transfer (informing) (Larios, 2015: page 22). For this reason, there is a series of taxonomies: rehabilitation games, educational games or serious games in general (Caserman et al., 2020). Other researchers like Gros (2009) maintain that there are seven modalities that can be found in serious video games. They correspond to the following areas: a) health, b) advertising, c) training, d) science and research, e) programming, f) education and g) production. Prieto and Medina-Medina (2016) highlight interaction as a factor of classification; in this sense, serious video games can be: standard interaction associated with the use of fingers in order to play, active interaction, in which the body is used as a tool to play and persuasive interaction, where the aim is to integrate the video game and the real-life context.

Video games and other digital resources meet the need for interaction, and also get students to interact with greater continuity and to use skills to make decisions and create strategies. Barr (2017) also mentions that the learning experience offered by modern video games includes a "predisposition" towards the learning exemplified by the games, requiring the players to be adaptable and ingenious; this means that they organize their available resources and experiment with them to find multiple ways of performing a task.

Due to the way in which serious video games are usually designed, i.e., with short-term objectives and a final long-term objective, students are kept motivated by the gradual progress of meeting the short-term objectives up until reaching the final objective (Llorens-Largo, Gallego-Durán, Villagrá-Arnedo, Compañ-Rosique, Satorre-Cuerda & Molina-Carmona, 2016). Another advantage they have is that they can be designed with a high level of personalization, according to their own requirements, providing the opportunity for immediate feedback and recommendations, which has the effect of reducing frustration and, in turn, increasing the effectiveness of the learning (Hung, Kuo, Chih-Yuan-Sun & Yu, 2014), not to mention that they give students the possibility to make mistakes in a safe environment where their actions have no consequences. Another important factor is that they limit the stress that students feel who take longer than others to reach their objectives, since they can move forward at their own pace (Dele-Ajayi, Strachan, Pickard & Sanderson, 2019).

Currently, the most prestigious universities and institutes have embarked on the task of evaluating the use of and research on digital tools, such as video games, as innovative educational tools (López-Rodríguez, Avello-Martínez, Baute-Álvarez & Vidal Ledo, 2018; Barraza-Macías, 2005). However, they are still not applied continuously, even to a lesser extent in university classrooms. In this regard, Gómez-Gonzalvo, Molina Alventosa and Devis (2018) explain that many instructors do not include leisure activities in their curricular materials, among them video games, as they are activities which relegate the instructor to the role of a mere spectator who applies certain materials, games, dynamics or digital resources created by others. In spite of this, it is in the field of engineering where the most studies have been published on games in higher education (Torres-Toukoumidis, Romero-Rodríguez, Pérez-Rodríguez & Björk, 2017; Clerici et al., 2021).

The use of serious games in engineering education has been accepted as an educational method for several years now. Given that noticeable changes are occurring in the technological and economic aspects,

these challenges can also be observed in the learning of engineering practices, which must be harmonized with technological evolution. Serious games can be effective in the study of disciplines such as programming (Campos, Nogal, Caliz & Juan, 2020) and can be used to give future engineers a better understanding of how their theoretical knowledge can be applied in practice. As mentioned earlier, it is also beneficial for future engineers to test their skills and knowledge in a simulated setting, in which there is less stress than in a real situation (Riera & Vigário, 2017). The effectiveness of interactive electronic learning for engineers allows us to demonstrate that games can be a very efficient practice and should be considered as part of university courses (Chachanidze, 2019).

In this sense, the purpose of the present work is to examine the use of serious video games in the field of engineering.

2. Methodology

The method followed for the present research was a systematic exploratory review (scoping review), which considers a review of a protocol within the phases to follow to specify the research question (Codina, 2021). The guidelines in the PRISMA-P2015 (Preferred Reporting Items for Systematic reviews and Meta-Analysis for Protocols 2015) statement were also followed (Moher, Shamseer, Clarke, Ghersi, Liberati, Petticrew et al., 2015).

The quality criteria were defined that allowed the selection of articles to be refined for the exploratory systematic review of the literature, as well as the inclusion and exclusion criteria. Four research questions were established for the analysis of the articles.

2.1. Objectives and Research Questions

Specific Objectives	Research Questions
To identify the types of video games that are used in engineering education	RQ1 What type of video games are used in engineering education?
To determine how serious video games are used in engineering education	RQ2 How are serious video games used in engineering education?
To indicate the level of educational acceptance by instructors and students with regard to the use of serious video games	RQ3 What is the level of educational acceptance by instructors and students with regard to the use of serious video games?
To know the findings regarding the advantages of using serious video games in engineering education	RQ4 What are the findings with regard to the use of serious video games in engineering education?

Table 1. Objectives and research questions

2.2. Search Strategy

The following search formulas were used in the Scopus and Web of Science databases: (search date: September 28, 2021).

2.3. Inclusion and Exclusion Criteria

The inclusion criteria that were considered in this review were the following: a) The articles must focus on the use of serious video games in engineering education; b) they must be open access for the readers; c) the type of publication must correspond to a scientific article or conference paper; d) the articles must be written in English or Spanish; e) the articles must be published between 2016 and 2020; f) the area of study must correspond to Computer Science and Engineering.

Excluded were those articles that did not consider the aforementioned aspects, i.e., those that were not related to the topic of study; that required payment from the reader; that have been published as other forms of academic and scientific communication, for example, book chapters; and those that correspond to other areas of study, such as the Humanities or Social Sciences.

Likewise, the fact that the studies form part of educational and/or technological innovation processes at the institutions of higher learning was also considered among the quality criteria.

In the initial search carried out in both the Scopus and Web of Science (WOS) databases, a total of 474 articles were identified. After applying the first filter, considering the inclusion, exclusion and quality criteria, only 45 articles were considered (40 from Scopus and 5 from WOS). Four were eliminated because they were duplicated in the two databases, and thus 41 articles remained. Finally, 6 articles were excluded because their contents were not pertinent to the study, and as a result only 35 works were considered, as shown in Figure 1.

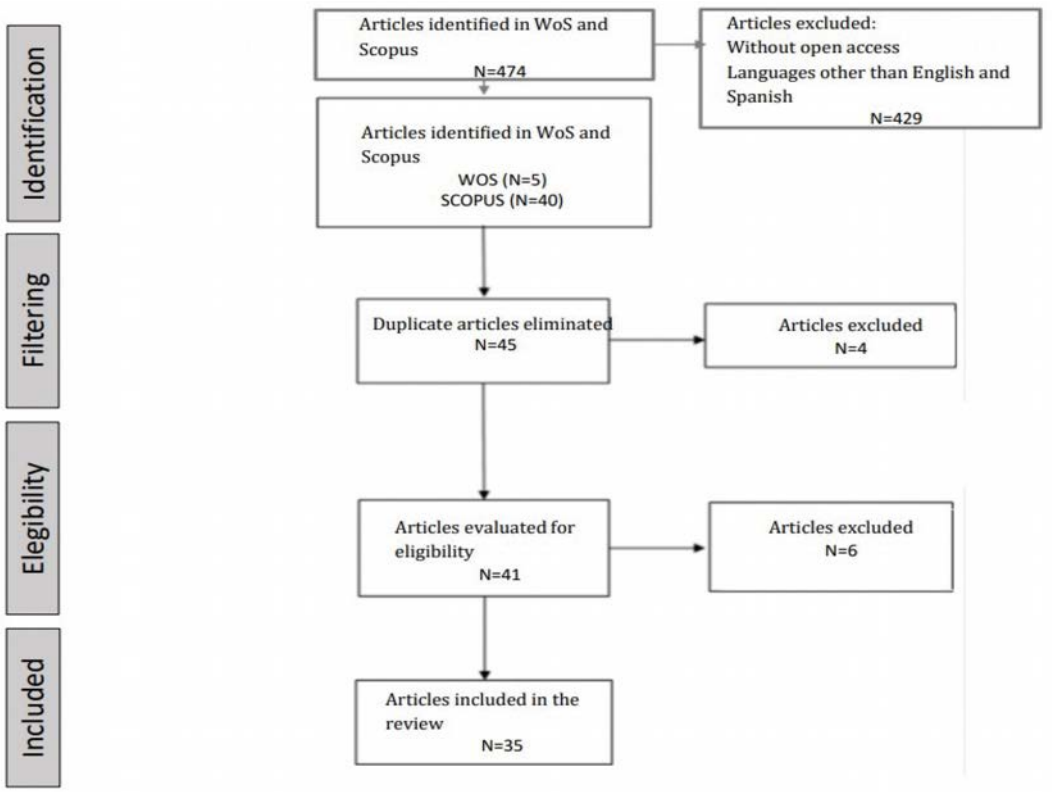

Figure 1. Prisma diagram for the Scoping Review

The 35 works selected in this systematic exploratory review are shown in Table 2.

No.	Citation	Brief description of the game	Course/Program/Area of application
1	Agterbos, Aldershoff, Cawley, Jung, Kehoe, Klok et al. (2019)	Exergame (fitness game) associated with the software creation and gamification process.	Interdisciplinary course: "Serious Game and Welfare Technology"
2	Ahmad & Liukkunen (2019)	*Marshmallow Challenge*, *Draw Toast* and *Scrum Simulation* are games that promote team work.	Software Factory Project (SWF) at the University of Oulu
3	Alonso-Fernandez, Calvo, Freire, Martinez-Ortiz & Fernandez-Manjon (2017)	Game Learning Analytics is an application that combines the educational purposes with game technologies.	EU H2020 SG projects
4	Ardic, Yurdakul & Tuzun (2020)	*CRSG* (Code Review Serious Game) is a game in which the students correct codes.	Software design course
5	Callaghan, McShane, Eguíluz & Savin-Baden (2018)	*Circuit Wars* is a video game for computers that teaches about basic electronic circuitry.	Electronic engineering

No.	Citation	Brief description of the game	Course/Program/Area of application
6	Callaghan, Savin-Baden, McShane & Gomez-Eguiluz (2017)	*Circuit Warz*is a video game for computers that teaches about basic electronic circuitry.	Electronic engineering
7	Callaghan, Mcshane, Eguiluz, Teilles & Raspail (2016)	*Circuit Warz*is a video game for computers that teaches about basic electronic circuitry.	Electronic engineering
8	Calvo, Rotaru, Freire & Fernandez-Manjon (2016)	Commercial Off-the-Shelf (COTS) Games, Games as a Service (GaaS)	General engineering
9	Campos et al. (2020)	Simulation game to learn the C programming language. Simulation game that teaches different areas of product manufacturing.	Electronic engineering course at the Polytechnic University of Valencia Department of mechanical engineering and manufacturing at Trinity College in Dublin
10	Cook-Chennault & Villanueva (2019)	*Build-Truss* is an application that helps students learn to design truss structures.	Course on Static Engineering in Mechanical Engineering
11	De Carvalho, Cerar, Rugelj, Tsalapatas & Heidmann (2020)	*Scratch, Snap and Alice* are online games that teach students how to program.	Software Engineering
12	De Carvalho, Escudeiro, Rodríguez & Nistal (2016)	*eCity* is a virtual city simulation game for learning based on engineering problems.	Universities of Greece and Turkey
13	De Vin & Jacobsson (2017)	*Karlstad Lean Factory* is an online simulation game that teaches about processes and materials.	Manufacturing courses at Karlstad University
14	Dinis, Guimaraes, Carvalho & Martins (2017)	Virtual reality games to learn introductory concepts of Civil Engineering.	Course at the Engineering college at the University of Porto
15	Flores, Paiva & Cruz (2020)	*EEEE—Expert and Efficient Estimators Enterprise (EEEE or E4)* is a game that teaches software estimation.	Software Engineering
16	Haendler & Neumann (2019a)	Software Refactoring**,** a game in which the user completes tasks guided by an instructor.	Software and refactoring classes
17	Haendler & Neumann (2019b)	The Refactoring Game makes it possible to analyze and design games for refactoring of software for education and entertainment.	Practical classes in computer programming and software engineering
18	Heikkilä, Paasivaara & Lassenius (2016)	*GetKanban***:** Virtual board game. Teaches Kanban, a workflow management method that is appropriate for managing continuous software engineering work.	Software engineering classes
19	Jantke, Schmidt & Schnappauf (2016)	*GORGE*, a digital game for technology transfer.	Artificial intelligence studies
20	Jaramillo-Alcazar, Guaita, Rosero & Lujan-Mora (2018)	*GameOhm* is a mobile application that presents interactive exercises related to Ohm's law. It has a translation into sign language.	Physics classes
21	Larenas, Marín & Giachetti (2018)	*Classutopia* is a role-playing game in which flaws in diagram designs are solved.	Design classes
22	Moloney, Globa, Wang & Roetzel (2017)	*Low Poly* allows the player to design sustainable spaces.	Architecture and engineering classes
23	Morata, Fernandez, Freire, Martinez-Ortiz & Fernandez-Manjon (2019)	*Game Learning Analytics* is an application for the analysis of responses and results of video games applied to students.	Classes based on games or digital platforms
24	Perez-Colado, Alonso-Fernandez, Freire, Martinez-Ortiz & Fernandez-Manjon (2018a)	*Game Learning Analytics* is an application to evaluate the performance by students on virtual games.	Classes based on games or digital platforms

No.	Citation	Brief description of the game	Course/Program/Area of application
25	Perez-Colado, Perez-Colado, Martinez-Ortiz, Freire-Moran & Fernandez-Manjon (2017)	*eAdventure's* is a platform for designing serious video games.	Visual or video game design classes
26	Perez-Colado, Rotaru, Freire, Martinez-Ortiz & Fernandez-Manjon (2018b)	Various games about geolocalization and movement, such as *Pokemon Go* and *Ingress*.	Engineering courses involving geolocalization
27	Ravinder-Reddy, Satyanarayana, Jagadesh-Kumar & Sreeram-Reddy (2020)	Various applications and virtual platforms.	Applied engineering courses
28	Riera & Vigário (2017)	*HOME I/O and FACTORY I/O* are two 3D simulators, taking students to a virtual house and factory. To represent real processes.	Structural design courses
29	Riera, Emprin, Annebicque, Colas & Vigário (2016)	*HOME I/O* is a simulator that allows users to apply concepts from the sciences, technology and mathematics.	Structural design courses
30	Riera, Annebicque & Vigário (2016)	*HOME I/O*, a simulator in which the instructor participates.	Structural design courses
31	Severengiz, Seliger & Krüger (2020)	*Factory Planner* is a board game that is complemented by a mobile app.	Undergraduate classes, related to decision-making
32	Smith, Hickmott, Bille, Burd, Southgate & Stephens (2016)	*Apostrophe Power*, a mobile app to improve written composition.	Online courses from the University of New Castle
33	Tsalapatas, De Carvalho, Heidmann & Houstis (2019)	Digital platforms for problem solving.	Engineering courses in Europe and Asia
34	Ünlü, Ardlç & Tüzün (2020)	Code Review Serious Game (*CRSG)* is a game in which students correct codes.	Software design course
35	Wang, Rajan, Sankar & Raju (2017)	Design game: an experimental platform designed for class development.	Product design classes

Table 2. Works found

3. Results

3.1. RQ1: What Type of Video Games Are Used in Engineering Education?

First of all, the most recurrence was found for simulation video games (4, 5, 6, 7, 9, 12, 13, 14, 15, 34, 35), which attempt to recreate activities or situations in real life, coming as close as possible to reality. Similar to the simulation is the construction and design of sustainable spaces that include rewards and levels to access different design tools (22).

Role-playing games are also present (20, 21, 32) with *Classutopia* (21), which offers challenges for class modeling, and mobile games focused on problem-solving and the completion of levels (20, 32). To a lesser extent, but along the same lines is CODING4GIRLS, a European initiative that sets out to teach programming through a serious games design and development process (11). Board games were also used, but adapted to the online environment and in a cooperative manner (18, 31).

On the other hand, the use of logical video games stands out, also referred to as "puzzle" games (10, 11). Likewise, the use of Virtual Reality (VR) and Augmented Reality (AR) was found in the learning process (14 and 27). Geolocalization video games related to spaces and user movement are also highlighted (26).

3.2. RQ2: How Are Serious Video Games Used in Engineering Education?

Among the simulation games is the CRSG (*Code Review Serious Game*) game, where the goal is to precisely simulate a real-world scenario in which to use Code Review, a process used in the industrial open code software community, while attempting to incorporate learning objectives (4 and 34). The game *Circuit Warz*, which is intended to teach electronic circuitry theory, allows students to experience the action

through the eyes of the main character, who must fix a giant laser in order to defeat invaders who threaten the well-being of the planet. The game is designed to complement the teaching resources while ensuring a high level of user participation (5, 6, 7).

Likewise, simulation games were used for the teaching of programming. In a certain video game, a submarine is introduced that must complete a certain rescue mission. As part of the game, questions are asked about the C programming language and students must respond correctly in order for the submarine to keep moving forward. In another game, the player makes a series of necessary decisions in order to manufacture hair dryers; the main goal is to show students the specific work roles in order to let them imagine the type of work they could do as engineers (9).

In (15), the mechanics of video games simulate a team of developers who undertake a project with specific requirements: simulating an iterative and continuous software development process. The game focuses the player on task estimation as part of a team of developers who use the *Planning Poker* methodology. The tool *Low Poly* (22) simulates the creation, design and construction of sustainable spaces; using problems and tools, the player must measure and create spaces that do not affect their environment.

Along the same lines, *eCity* is a city simulation game that supports a Problem-Based Learning (PBL) instructional methodology in secondary schools, and at the same time, promotes the interest of students to pursue a career in engineering (12). In *Karlstad Lean Factory*, the factory setting is emulated in a realistic manner, with a combinations of processing and material assembly, precisely to teach students about processes and materials (13). In order to teach about the production design concepts, a game was created in which users can select from among a set of structures, materials, lengths and types of joints to build a structure. Later, the game simulates the estimated load that the structure would support (35).

Among the puzzle-type video games is *Build-Truss*, an educational tool that emphasizes the topics of structural stability that are seen in the static courses (10). Likewise, Kanban is used, which is a method of flow management that is applied in software engineering; it is taught within an online cooperative board game called *GetKanban* (18).

The games *GameOhm* and *Apostrophe Power* (20 and 32) are mobile applications. In the first case, users are given some educational quizzes on Ohm's law in order to put their skills to the test in the areas of voltage, current and resistance; provisions are made for hearing-impaired students. In *Apostrophe Power*, the application allows students to complete writing exercises as a supplemental activity for engineering students. In the case of *Classutopia* (21), students choose a character to correct class diagrams; this game, in particular, provides feedback, i.e., the player receives recommendations and corrections if they fail a mission.

On the other hand, *Game Learning Analytics* (3, 23 and 24), while not exactly a video game, is a digital tool that lets the instructor verify, analyze and receive scores for students on video-entertainment activities. Furthermore, it helps with the analysis of games, for their proper use in certain topics. With regard to the previous tool, there are also platforms for creating video games (25), which while basic, are very dynamic, called *eAdventure*. These are low-cost and require no knowledge of programming, which allows those interested to develop educational games. These platforms have a diverse use, since they can also be used to create virtual laboratories (33) where students practice selected exercises from Asian and European university databases; all of this is focused on certain engineering subjects. Their online nature allows them to obtain feedback and at the same time, support instruction.

Other studies (26) based on video game analysis highlight and identify those related to the topic of geolocalization and movement, such as *Pokemon Go* and *Ingress*, for which they suggest an extension called xAPI, which permits analyzing the places visited. These types of games are also suggested for use in laboratories. Likewise, the software packages *Virtual Training Studio*, *Animated Assembly* and *Virtual CNC machine* (27) are also recommended. *Home I / O* and *FACTORY I / O* (28, 29 and 30) are two 3D simulation software packages that can be used to create a virtual house, where students can explore and work with certain materials, such as laboratory supplies or certain machines. This is a means of

entertainment and the simulators are used to anticipate any possible errors in the field in real life. One special case is *Factory Planner* (31), which is based on VDI 5200, a board game that is improved by the use of an application that allows students to tackle real-life problems related to structures and digitalization. Another study (19) investigates the concept of mind theories and the user/learner/player relationship.

3.3. RQ3: What is the Level of Educational Acceptance By Instructors and Students with Regard to the Use of Serious Video Games?

Educational acceptance can be classified as high, especially in the case of students (1, 2, 4, 9, 13, 14, 15, 17, 20, 22, 27, 28, 29, 30, 31, 32, 33, 34, 35). Students indicate that, thanks to serious video games, their knowledge has increased, and their technical and development skills have improved (1, 2, 13, 20, 27); they also mention that they serve to learn to review and practice their Java skills (4, 34), which gives them the possibility to learn new problem-solving approaches during complex decision-making processes (9). Some students point out that they not only achieved most of the expected learning objectives, they did so in a pleasant way while having fun (15, 17, 22, 31); they also indicated that they concentrated better and enjoyed themselves when they perceived clear, useful objectives during the game (35).Likewise, improvements are observed in their skills and the desire to continue to complete levels (32). With regard to the Augmented Reality (AR) and Virtual Reality (VR) interfaces, both were important for the participants, and were even essential for understanding the material that was presented (14).

With regard to the 3D simulation software (28, 29, 30), the students, by becoming teachers/players, immediately joined in and understood the commands with great ease. Moreover, they show great motivation in their assigned tasks and the challenges proposed to them, for which they use logic and creativity, making it easy to learn new concepts.

On the other hand, it was found that while many students were open to the use of a serious video game for their learning, and they recommended including educational games for engineering as classroom learning tools, only a few indicated that they would use them to prepare for exams or technical job interviews (10). In some cases (21), not all the students were immediately able to understand the commands and how the game worked; however, more than 50% state that it is possible to understand concepts better with video games than when using texts; the designers also state that the results cannot be generalized, because the sample was small.

Among the instructors, there is also a high level of acceptance (8, 9, 10, 23, 24, 25, 26), since from their perspective, serious video games help connect formulas and mathematical concepts to real-life applications in different fields; the conclusion is that simulation games facilitate the development of analytical thinking by students (9). Instructors who use this tool in the classroom believe that it serves as a tool to support student learning in engineering, as a supplement to classic materials, such as textbooks and conferences (10). The preference is also mentioned for the games to include evaluation, monitoring and other classroom management functions (8).

There was only one study in which the pleasant experience of the video game did not fully translate into effective learning (18), and thus it could be considered to have a medium to low level of acceptance. When focused on educational video game design (25), instructors express an interest in the different applications available. One particular case corresponds to the *eCity game,* which meets the goal of fostering student interest in pursuing a career in engineering, since it is a game available free of charge in online stores and one that has been downloaded more than 100,000 times, thus showing the positive reception it has had by its target audience (12).

3.4. RQ4: What Are the Findings Regarding the Advantages of Using Serious Video Games in Engineering Education?

Except for in one case (18), the findings show that the use of serious video games in education should be encouraged, especially in the context of engineering, where professionals deal with complex models of real-life systems, and thus they need to receive specialized training in order to make informed decisions

that affect systems with multiples variables and elements that interact with one another (9). Serious games have a series of benefits: they are often used to augment the entertainment and participation factors in the learning process beyond those of traditional learning; at the same time, they have learning objectives and interactive elements (4, 27), which result in greater participation and better comprehension of the engineering principles in complex environments (13). Depending on the demands and the given context, this means that students can work on multidisciplinary teams to achieve a common objective (1).

Furthermore, they make it possible to put players in realistic situations, where they can learn through experience and improve their decision-making capacity (9).With regard to specific cases, the idea behind the use of serious games to teach programming emerges from the fact that by being attractive and motivating, they allow students to learn computational thinking skills in entertaining and familiar environments, before transferring these skills to the learning of a programming language (11). Even students recommend their use, due to their dynamic and demanding nature (31). Similarly, they can also be used with differently-abled students, making it easier for them to do certain exercises (20).

The findings also indicate a concern for the mechanics and dynamics of serious video games. There are studies that have led to recommendations for developers in terms of the characteristics that this type of video games should have (3, 7, 8, 9, 15, 33, 34, 35). Since serious video games have special requirements and there is still not a proven and widely accepted focus, each developer must choose the best options, taking into account factors such as the platform that will be used, the desired mechanics, the genre of the game, the learning objectives, the time and resource limitations and the compatible technologies, among others (8).

The efficient design of a serious game must ensure that the level of difficulty for the players is compatible with their knowledge and skills; in other words, it should be challenging enough to provide a sense of satisfaction to the player when they reach the objectives, and at the same time, accessible to prevent despair and frustration (9). In order to promote the design of new leisure experiences, tools like eAdventure (25) have been presented that do not require any specialization in design; however, this type of platforms still has some limitations. Simulations and software are also positioned as viable options for the preparation of complex tasks that require critical material (28, 29, 30). Another factor is to recognize what the best video games are and the different applications of those that already exist (26), so that they can be given new uses, with the help of extensions.

For the aforementioned reasons, formal methodologies are important, such as the conceptual framework of the Serious games model, based on activity theory (ATMSG) (7) and the methodology that relates the Learning and Teaching Functions (LTF) to Patterns of Game Design (PIB) that are used in Software Engineering instruction (15). The results indicate that these methodologies can help develop effective educational games on specific learning topics (7, 15). It can also be mentioned that Learning Analytics (LA) is very appropriate for analyzing data on student interaction in order to improve not only the learning process (3, 23, 24), but also to interpret the results of the players. They are also useful for identifying the best option to apply in the classroom and for a certain topic.

One unique case shows us the need to supplement the writing skills of engineering students with the use of *Apostrophe Power* (32), which with continuous use, helps improve writing skills and prevents errors. Recurring games and feedback are essential for learning (32, 20, 21, 22).

In a different line of research, it is seen that the use of video games can cause an involuntary perpetuation of inequality through the bias favoring students who enjoy learning based on competence and knowledge assessment, and the bias towards students who have prior experience in online games (10).

4. Discussion and Conclusions

The introduction of new methodologies and practices in engineering education, especially designed to motivate students, can improve and incentivize them during the learning process (De Carvalho et al., 2016). In this sense, serious video games are presented as potential teaching-learning instruments in engineering education. In this study, it has been found that there is an evident inclination toward serious

video games involving simulation by engineering students, which boost the educational process, as they provide challenging and immersive environments (Calvo et al., 2016) in which they teach or consolidate specific skills in the context of simulated situations. They are perceived as being more beneficial in terms of comprehension, application and knowledge transfer, and contributing more to the specific learning than other types of games (Riemer & Schrader, 2015). Secondly, it is also observed that there is a certain predilection for role-playing games and board games that have been adapted to a virtual environment. Although fewer studies were dedicated to them, mention was also found of AR and VR games, and geolocalization games.

In terms of how serious video games are used in engineering education, a wide variety of descriptions was found on how they were being used in specific ways to incorporate learning objectives, allowing students to complement the teaching resources that were previously provided, and to experiment with environments that are as real as possible. In general, applications range from mechanical activities, knowledge assessment and the simulation of complex real situations through virtual environments. Likewise, it allowed them to understand in greater depth the work that they will do once they are working in the field, and to firmly establish learning about processes and materials. This difference is noticeable from game to game, and the way in which serious games were used in education indicates that there are many types of learning content, which require different methodologies (Laporte, Zaman & Grooff, 2013).

In this sense, the importance is seen of having more studies on the methodologies that can help develop effective educational games on specific topics. Also worthy of mention are applications like *Learning Analytics* (LA), which are useful for analyzing and interpreting players' results (Alonso-Fernandez et al., 2017; Perez-Colado et al., 2018a; Morata et al., 2019).

A decisive factor is the simultaneous feedback and corrections of the exercises proposed as challenges and levels in the video games, which are given in different ways such as messages, alerts and clues that form a part of the game. They are beneficial for students and their learning, since by having help within the game, they can gradually move onto the different levels in an independent manner. The above means that the students are no longer merely passive spectators at lectures given by their professors, rather they actively participate and solve real-life situations in a virtual environment (Larenas, et al., 2018; Severengiz, et al., 2020). Feedback is essential in order to use serious games correctly in education (Peréz-Colado et al., 2018b). For this reason, it is important for the video game, virtual game or online game to allow students to obtain responses or cooperation in order to avoid frustration or mistakes.

With regard to the level of educational acceptance that serious video games have among instructors and students, they were found to be especially beneficial for the latter. Students remarked that the games helped them to achieve the learning objectives in most cases, and to do so in a fun, entertaining way. However, in spite of this, it cannot be ignored that there is also mention that serious games would not be used for the preparation of exams or technical job interviews. This indicates that the limitations and uncertainty that exist regarding their potential cannot be ignored, although much of this stems from the lack of reflection on the medium and the potential it has (López, 2016). For some instructors, the implementation of gamification is not yet possible, due to barriers and even the lack of knowledge. For this reason, applications are being created that let them include assessment matrices for student activities, thus allowing them to feel more comfortable with the video game interaction (Riera & Vigário, 2017).

In the review, it was also possible to identify the importance of using additional online resources and materials that are available in the video games, such as links and explanatory videos. These are tools that students can use during video games, which are very similar to the tools and materials that are used in role-playing or multiplayer video games. It is a very useful comparison between knowledge tools and strength tools. Swords, axes, weapons and construction materials are just as important as formulas, theoretical explanations and data that allow them to advance when organizing a code or creating sustainable designs.

The review indicates a broad interest in developing theoretical frameworks and tools that make it possible to evaluate serious video games, considering that they must balance the inherent element of fun with the

educational or instructional objectives in a way that is not overly intrusive and does not lose sight of the objectives (Giessen, 2015). This is due to the fact that currently, in spite of the large amount of research in this regard, the is really no formal political framework from governmental or educational institutions in relation to the incorporation of games and simulations in education (Vlachopoulos & Makri, 2017).

Another point that must be mentioned is the relevance of *Game-Based Learning Theory*, which describes a learning approach based on games; here, students explore important aspects of games in a learning context. Instructors who wish to benefit from gamification in the teaching of their students must learn how to implement it, specifically in relation to their educational objectives (Krath, Schürmann & von Korflesch, 2021). This is particularly substantial in today's socio-educational context, in which digital education and remote work have become more relevant than ever.

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