

Gamification Applied to Physics Teaching in Higher Education.

An Alternative to Achieve Better Results

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Abstract

This article shows the implementation of a didactic research on the application of a new tool or methodology called Gamification that involves the student, the ICT and the teacher in the same classroom, where through this technique contents, procedures and attitudes are learned in a playful environment while enhancing the motivation of students.

It has been detected, and it does not come from now, but from much further back, that the subjects called 'practical' and among them Physics, are the most difficult to assimilate for most students. Sometimes the student is faced with concepts that are not easy to assimilate and even less to understand by the application of a simple mathematical formula. This leads to a great demotivation of the students that make them abandon this type of subjects and opt for more theoretical careers. This is a fact that is more than contrasted in the current Spanish University, where the number of students enrolled in the career of Physical Sciences continues to decrease. The following are some interesting data regarding Physics degrees in Spanish universities (Sánchez, 2004).

- The average number of years it takes students to complete their degree from the time they enter the university is 6.49 years.

- The percentage of students who abandon their studies without completing them is as follows: Barcelona (40-50%), Autónoma de Madrid (50%), Vigo (31.81%), Valladolid (<3%), Oviedo (38%) and Cantabria (55.86%).

However, despite the above data, Physics will continue to be very important and is far from being the finished science that many predict. It will continue to be one of the main sciences of this century, not only for its own sake, but also because of what other disciplines will need from it.

The purpose of this project was to achieve a more significant and global learning of students in the concepts taught in Physics class and that students positively value the introduction of gamification as a motivational tool and support to strengthen the knowledge of the subject. The use of the gamification tool has led to an average improvement of 33.81% in students' grades.

Keywords: gamification; education; learning; game dynamics; didactic strategy

1. Introduction

1.1 Where it comes from and what gamification is

Under this perspective, there is no choice but to define and highlight what Gamification has contributed to this kind of pilot test that has been carried out in one of the Physics subjects of the Architecture Degree at the CEU San Pablo University in Madrid (Spain), however, before a brief overview of this methodology or learning aid tool will be made.

The term Gamification appeared in the digital media industry around 2008. The most accurate definition of what this term means appears with "gamification consists of using game-based mechanics and strategies (whether video games, role-playing games or digital environments) in order to encourage students, motivate them to action, promote learning and problem solving" [3, 8].

Using a digital device in the classroom does not mean gamification, for this it is necessary to make use of the basic principles on which all games are based (digital, board, role-playing, digital environments, etc.), the mechanics, dynamics and components of the game.

The mechanics of the game would include the tasks of positive reinforcement, earning points, climbing positions within a ranking, winning prizes, leveling up, succeeding in quests and challenges, etc. [7, 18, 25]. In the dynamics of the game, the personal concerns and motivations of students to perform and contribute to the gamified task are established. As examples we have achievements, classroom competitions, rewards upon completion of a challenge, companionship to perform and complete the task. To achieve all this there are many techniques, but the most

used are reward, status, competition, altruism, expression and achievement [2, 4]. Finally, the components of the game will be taken into account, which will be very varied and will depend on the type of task set. Examples of these are table-ros, game areas, character avatars, badges, medals, social status among the group of students who are involved in the gamification, etc.

In an educational environment, the benefits of incorporating game elements provide extra motivation for students [5, 6, 7]. In this environment, students are allowed to progress at their own pace through personal and timely feedback, in addition to developing skills such as problem solving, collaboration and communication. Currently, students are satisfied with the use of technological tools to support their teaching and learning process, but we must activate new processes and establish which typology of Gamification tools improve results in each specific case. As for the methodology of rewards when recognizing the efforts of each student or group, there is a wide debate as to whether they should be physical prizes, qualities obtained, educational bonuses or access to virtual games/platforms [15, 18, 22].

This is perhaps the most critical point of a methodology in which constant learning is highly valued and which is beginning to be implemented in many educational centers.

The idea of Gamification is not to create a game, but to use the tools we have to get used to the system: Pursuit of an Objective - Goal - Achievement – Reward [19].

The interest of applying the gamification tool in the learning and development of students in the subject of Physical Foundations of Architecture II in the first year of the Degree of Architecture lies in innovation and motivation towards action. It is important that teachers and students of the 21st century adapt and gradually incorporate the use of new educational technologies.

It's important to analyze the advantages and disadvantages provided by this new tool, so that the different characteristics that this new resource can offer as support material during the current teaching-learning processes will be presented. It also incorporates the approaches of different activities that can be used as an orientation for its later application in the Primary Education stage. The aim is to show the potential of ICT in the educational field, focused on gamification, as a teaching strategy in the teaching-learning processes [2].

1.2 Gamified teaching strategies

They are part of the pedagogical experience in which the teacher demonstrates skills and abilities in the learning and teaching processes, which leads to matching criteria and procedures to form the teacher's attitude in the classroom focused on motivating, stimulating and energizing the knowledge acquired by students in their interactions in groups, among students and with the teacher.

Pedagogues [8, 12, 15] state that there are a series of active methodological-strategies:

- Didactic strategies focused on 'learning to create' that allow a more orderly and objective appropriation of knowledge [20, 21].
- Illustrative strategies that are a visual representation of the objectives, concepts or situations of a specific topic (drawings, photos, diagrams, etc.).
- Socializing strategies that aim to develop understanding, autonomy, personality and increase self-awareness.
- The teaching of gamification has been the focus of this work because it facilitates the acquisition and internalization of knowledge in a more fun way, leading the student to more positive experiences.

So that the student can better perform and achieve their learning objectives. Certain dynamic techniques are used to play and continue in the achievement of their goals. Some of these techniques are reward (obtaining a deserved benefit), status (establishing a valued academic hierarchical level), achievement (personal satisfaction or accomplishment) and competition (trying to be better than others and to be able to stand out).

1.3 Differences between gamification, serious games and project-based learning

It is necessary to distinguish between these terms. Gamification is seen as a learning technique that transfers game dynamics and its resources to a non-game scenario, as mentioned at the beginning of this study. It uses resources such as rankings, rewards, badges, prizes or point systems.

Serious Games (JS) are generally computer-simulation programs, virtual reality or video games whose main objective is not fun or entertainment, but learning or practicing skills [1, 24].

And finally, Game-Based Learning (GBL) is a method that uses games to learn. When the contents and skills that want to be taught are not presented in a pre-classroom, online class or in a book, but through games.

1.4 Characteristics of Gamification

The most important characteristics of gamification are the following: it uses game mechanics in non-game environments, such as an e-learning course, corporate training, formal and informal education, etc. (for example, awarding points and medals when different activities are passed, making a ranking where the progress of students is shown globally, organizing contests, etc.); its main purpose is to motivate people to perform certain tasks, achieve learning objectives, and ultimately, complete the course. In general, it is not applied to the whole, but to certain elements (evaluations, grades, course progress, etc.) with the purpose of improving the learning experience [10, 23]. It is convenient not to apply gamification

to all the elements of the course, i.e., not to turn every activity or resource into a tool to get compete, get medals.

It will be necessary to delimit the problem indicating the field of application (education), the area (subject of Physical Foundations of Architecture I), the aspects (pedagogical, technical, didactic and cognitive), the title (the application of gamification in the subject), the proposal (study and evaluation of the application of gamification) and the context (first year subject of the Architecture Degree of the Polytechnic School of the CEU San Pablo University). It will also be necessary to study the operability of certain variables that are listed in the following table:

VARIABLES	CONCEPTUAL DEFINITION	OPERACIONAL DEFINITION	INDICATORS
Gamification	Learning technique that transfers games to the educational-professional environment with the aim of achieving better results, either to better absorb some knowledge, improve some skill, or reward specific actions among many other objectives.	Gamification teaching strategies.	Dynamics applied to student performance.
			Implementation of game patterns in the educational curriculum.
Development Cognitive (CD)	CD is the process by which a person acquires knowledge about his or her surroundings, thus developing his or her intelligence and capabilities. It begins at birth and continues throughout childhood and adolescence.	Cognitive development process. Meaningful learning.	Game strategies.
			Game mechanics in the teaching environment.
			Stages of cognitive development.
			Usefulness of meaningful learning.
			Advantages in academic performance.
			Active technological methods.
			Interactive methodology. Active learning techniques.

Table -1 Operationalization of variables

It will also be necessary to indicate the premises of the research in terms of methodological strategies of gamification to encourage students, better tools for teachers to reward students, motivate students to strive to achieve cognitive development. The application of gamification to the teaching of Physics can teach them to make this teaching more fun and try to erase previous boundaries that disable the student to study. The activities developed with this tool can lead the student to cognitive development depending on the success of the assimilation of the new contents.

2. Method

2.1 Population and sample

The methodology is presented as the connector between the researcher and the object of research, without it it is unlikely to reach the logic that leads to scientific knowledge. Therefore, it is very important that the teacher establishes the correct methods in the types of research and methodologies to obtain the objectives and goals that he/she intends to achieve in his/her educational project.

Regarding the modality of research, quantitative and qualitative approaches can be given, in the first one it will be used for data collection to test hypotheses attending, for example, to statistical analysis; in the second one it will be used to ask research questions in the process of data interpretation. In this work, both modalities have been used. Regarding the types of research, a bibliographic research has been carried out, a field research that has allowed obtaining data on the application capacity of gamification in the subject and determining the cognitive development of the student; and an exploratory research that has led to the elaboration of different hypotheses to help in the subject of the surveys.

In the research methods: scientific observation, inductive method, deductive method and correlational method, most of them have been used in the study. The same has occurred if one takes into account the research techniques: observation, survey and interview. The population focused on a group of people who have a common characteristic to be able to do the research and who help with their opinions and criteria to study the problem of the introduction of gamification in education.

For the sample, some elements of the population are selected to calculate the statistics, and consequently estimate the population data. In this research, the same group of Physics students from the population has been selected as a sample, because it does not exceed 100 subjects, it is a non-probabilistic sample. In this type of sampling, the samples are collected in a process that does not offer the same opportunities to all the elements of the population. The surveys and an observation form were applied to the 37 students in the Physics group.

Ítems	Levels	Frecuency	Percentages (%)
1	Students	37	79
2	Teachers	1	2
3	Heads	3	6
4	Legal representatives	6	13
TOTAL		47	100

Table 2. Sample distribution

2.2 Analysis and interpretation of results

Survey applied to the students of the subject of Physical Foundations of Architecture II of the first year of the Degree of Architecture (Contreras, 2016). The students have evaluated the work of the teacher by applying gamification techniques to the subject around three dimensions of quality: academic rigor, teaching qualities and methodology and didactics. The scale of measurement was A: Strongly agree, B: Fairly agree, C: Slightly agree and D: Very little or no agreement. Nine students participated out of a total of 37.

- Academic rigor: to evaluate this dimension, five questions were asked according to the following scale.

ACADEMIC RIGOR	A	B	C	D	Percentages
The application of gamification in the course has been reported.	7	2	0	0	75,55% (A) 22,22% (B) 2,23% (C) 0,00% (D)
The contents and activities introduced respond to the objectives.	7	2	0	0	
The classes and activities have been planned and developed conveniently.	8	1	0	0	
The materials and bibliographies for the implementation of gamification have been useful.	6	2	1	0	
The grading system reflects the work and activities carried out in the new gamified environment.	6	3	0	0	
TOTAL ACADEMIC RIGOR:	34	10	1	0	

Table 3. Teacher's academic rigor with application of gamification in the subject.

As can be observed in this evaluated dimension, there is a clear tendency towards the teacher's academic rigor, even when gamified techniques are introduced in some parts of the course syllabus.

- Teaching qualities: in order to evaluate this dimension, four questions were asked according to their scale.

TEACHING QUALITIES	A	B	C	D	Percentages
Demonstrates mastery of the gamification technique and its introduction in the subject.	8	1	0	0	72,22% (A) 22,22% (B) 5,56% (C) 0,00% (D)
Is available to answer questions and doubts in class and tutorials.	6	3	0	0	
Encourages participation and interest to have a relationship with the subject and applied gamification	7	1	1	0	
Offers an applied and interrelated gamified content.	5	3	1	0	
TOTAL TEACHING QUALITIES:	26	8	2	0	

Table 4. Teaching qualities of the teacher with application of gamification in the subject.

In this other dimension, the majority of students think that the teacher has good teaching qualities and that he/she integrates gamification perfectly with them within the chosen or pilot subject.

- Methodologies and Didactics: to evaluate this dimension, three questions have been asked according to its scale.

METHODOLOGY AND DIDACTICS	A	B	C	D	PERcentaGes
Promotes the capacity for reflection and reasoning by applying gamification.	7	2	0	0	70,37% (A) 29,63% (B) 0,00% (C) 0,00% (D)
Stimulates student learning and work outside the classroom with the new tool.	5	4	0	0	
This tool has provided significant learning for my training.	7	2	0	0	
TOTAL METHODOLOGY AND DIDACTICS:	19	8	0	0	

Table 5. Methodology and Didactics applied by the teacher with application of gamification in the subject.

In this other dimension, the evaluation focuses on only two scales, showing for the most part that the methodologies and didactics used by the teacher with the

introduction of the new tool are very satisfactory.

All of the above data collected from the student surveys can be summarized in the graph in Figure 2.

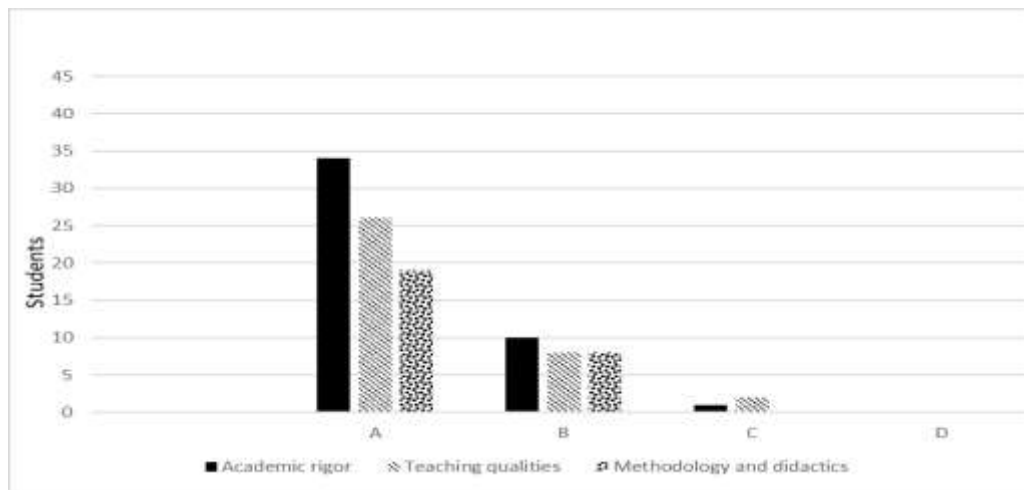


Figure 2. Evaluation of the dimensions of teaching quality in the teaching staff.

Figure 2 clearly shows how the positive results are centered on scale A of 'Strongly agree' of the evaluation made by the students. The results obtained for scales B and C will be used to study the cases detected that can be improved in the application of the new technique, trying to improve the feedback processes both in terms of subject matter and ways of introducing the tool.

On the other hand, the evolution/performance of the students before and after applying the gamification tool was also measured. For this purpose, the grades of the first partial were compared with those of the second (gamified classes) including the total number of students. The following table shows the data collected from the grades of the students of the group analyzed.

Student	FM	SM	Student	FM	SM	Student	FM	SM	Student	FM	SM
S1	7,9	7,5	S11	NP	NP	S21	2,4	3,8	S31	NP	NP
S2	4	4,9	S12	NP	1,5	S22	1,7	6,5	S32	0,2	NP
S3	4,7	7,7	S13	NP	2,3	S23	5,1	6,9	S33	3,7	5,4
S4	NP	1,4	S14	NP	NP	S24	7,6	8,5	S34	2,2	NP
S5	4,1	5,1	S15	NP	NP	S25	2,3	4,6	S35	2,4	4,2
S6	NP	NP	S16	7,2	9,4	S26	NP	NP	S36	0,8	4,4
S7	1,5	3	S17	6,1	7,8	S27	1,4	2,1	S37	1,9	7,5
S8	2	3,6	S18	NP	NP	S28	6,6	7,2			
S9	7,2	7,6	S19	8	8,7	S29	6,2	6,8			
S10	5,6	4,5	S20	4	5,5	S30	NP	NP			

Table 6. Grades obtained by the students in the two mid-term exams of the course

The table above shows the grades obtained in the two mid-term exams. The students are indicated from S1 to S37, FM corresponds to the grade of the first midterm, and SM to the grade of the second midterm. NP indicates when a student did not show up for the midterm. In this study, this condition appears for students who have not attended either of the two midterms: S6, S11, S14, S15, S18, S26, S30 and S31 (eight cases). There are some cases where the student has only attended one of the two midterms, such as students: S4, S12, S13, S32 and S34) (five cases). The rest of the students (24 of the 37 total), have presented themselves for both midterms.

The data in the table are shown graphically below for better interpretation and analysis.

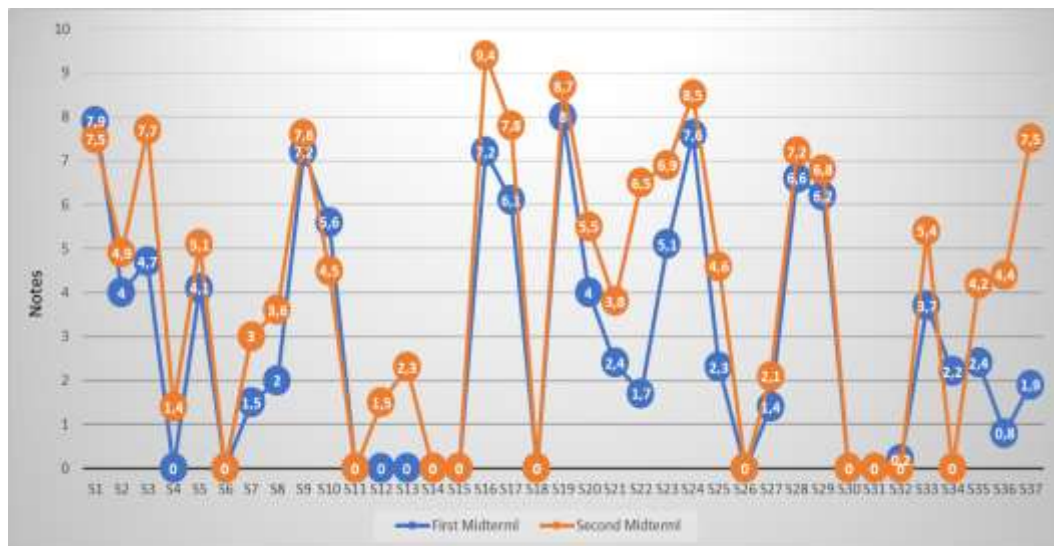


Figure 3. Comparison of students' grades between the two mid-term exams (the second with gamification).

Figure 3 shows on the x-axis all the students from the first student S1 to the last S37. The total number of students enrolled in the course of Physical Foundations of Architecture II was 37. In the first partial the students of the group obtained an average grade of 4.11 points, and in the second partial (including gamification) a grade of 5.50 out of 10. The difference between both averages is 1.39 points, representing an average improvement of the students of 33.81%.

As shown in Figure 3, it is worth noting that the grades of the second partial where gamification processes have been applied in some of the classes (orange line) are above the blue line (non-gamified class) in almost all cases, except for students S1 and S10. A total of 11 students did not show up for the first midterm,

while 10 students did not show up for the second midterm. At first glance, it might seem that gamification did little to encourage students to take the second midterm. In general, the students who did not show up for one or the other midterm, or even for both midterms, total 13 students, of which 5 of them, due to the gamification, felt motivated to take the second midterm without having taken the first one, which means that 38.46% felt motivated to take it in spite of their grade.

There are cases where students have not improved the grade of the first midterm, despite the application of gamification techniques, as is the case with students S1, S10, S32 and S34. On the contrary, the rest of the students (22 of the total) who have taken the two mid-term exams have managed to increase their grade, which represents 59.45%.

3. Results

The implementation of gamification techniques in a single subject of the Degree of Architecture to improve student performance through pedagogical and didactic research has not been excessively complicated. The most delicate thing is to choose that part of the subject where you want to implement this technique to obtain the objectives set and how to apply the technique at that moment. In the adaptation used for this study, it has been applied under the title "Physics through time against Superheroes" in the subject of Physical Foundations of Architecture II.

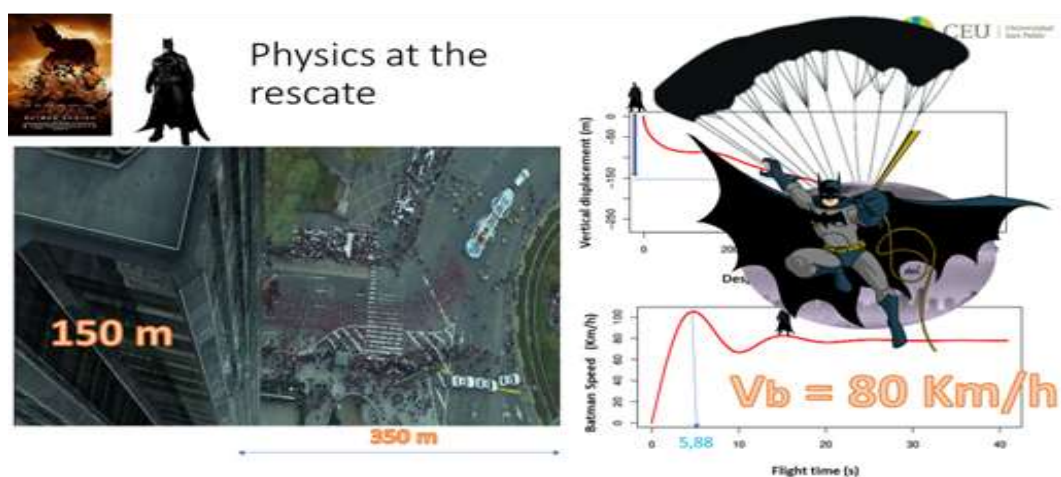


Figure 4. Study of the fall of Batman, will he still be alive?

We have proposed the creation of worksheets with the choice of the favorite superhero and the description of his superpowers, this has allowed the students to be very motivated with Batman, Spi-derman, Superman, etc. The choice of small pieces of film has been complicated, since the physical problem to be studied should be adapted to the topics covered in the syllabus of the subject. Confronting the laws of Physics, basically Newton's laws, to these paranormal phenomena and determining if this particular behavior was possible, explaining the reasons why, has been very interesting for everyone. Some students knew more about Physics than they were saying, perhaps it was their motivation and commitment that raised their level.

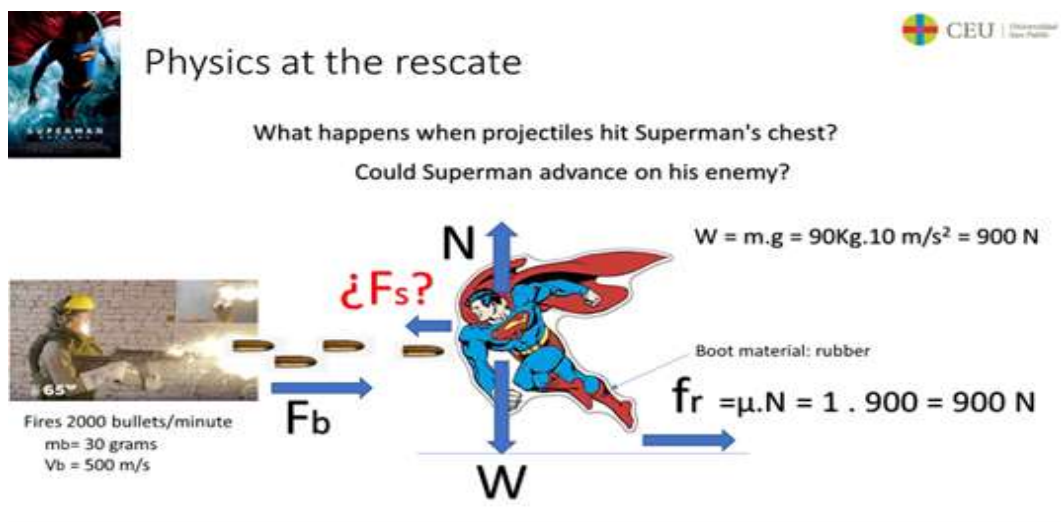


Figure 5. Superman in action, is what happens possible?

On the other hand, the analysis of small pieces of superhero movies has allowed the school to have a small video library for the realization of future projects, perhaps more ambitious. It has already been applied to students with reduced abilities in lectures related to the subject and has been a great success.

Collaborative work in groups and then inter-groups was decisive to reveal all the secrets of Physics and its application. The use of ICT was fundamental to develop all the stages of the Project based on the new tool [16].

Keeping students motivated and valuing their work fairly were two of the main problems. When working with groups of five or six students, on some occasions some students were disconnected and had to be assigned another role within the group (moderator, team captain, etc.). It was also difficult to fairly evaluate the work of each student, so in the end we opted for a group grade (in the assembly and exhibition of the final video where they analyzed and explained some 'strange behavior' of a superhero) and an individual grade. The group grade was given by

the whole class, being ten for the best work and four for the worst (all out of 10 points). The individual grade was given only by the teacher on a scale of zero to ten.

Finally, each group, after pooling everything they had covered in Physics, created the superhero of the 21st century with the justified superpowers they thought he should have, trying not to infringe too much on the laws of Physics. This turned out to be an interesting section of the project, entering into social, religious, political and, of course, scientific issues.

The pedagogical aspect of the Project supports the reason for the research work developed within it, since it is directly related to education and the use of the gamification technique [13, 14], producing as we have seen a better empathy with teachers and greater motivation of students in the assimilation of concepts difficult to understand, such as those seen in Physics, and thus tending to a higher academic performance of students.

4. Discussion

The introduction of gamification is important because it acquires the role of a motivational tool, since it can transform extrinsic motivation into intrinsic motivation, thus awakening the student's passion for learning and an enormous need to learn significantly, valuing that the development of a gamifying activity is for the benefit of the student himself [9].

Gamification in education carries with it an enormous responsibility for the objective to be achieved and for the addressee of the process. It should be taken into account that young students, many times in training, are easily malleable and will be motivated if the processes are developed properly; however, if the processes are not sufficiently clear, demotivation usually appears when they are not able to understand what is intended for them.

A gamified class survives with arguments centered on the game but implemented as learning experiences that use challenges in real situations and choices whose level of difficulty is increasing, so a gamified class should have an attractive story that allows converting the learning objectives into challenges to overcome [11]. The success of a gamified class in the higher education context should have a series of daily objectives in accordance with its methodological planning, which should have a system to measure their progress; this is because an educational system that uses gamification is guaranteed to reduce stress and anxiety levels, paying more attention to the involvement in the game. Gamification as a support for the university teaching strategy eliminates the uncertainty about why I learn and with what I learn, as well as the monotony of the expository model, since the

implementation of a gamifying activity helps both the student and the teacher to objectively know the level of progress in the personal learning of each individual based on his or her own interests. As a general consequence, it is determined that gamification positively affects the learning process by stimulating motivation in students, particularly through the positive interaction between teacher and students.

Young people are extremely binary and want things to happen as soon as possible in their thoughts and tastes, so a gamification process may face several problems of not quickly achieving the motivation and immersion of students in the programmed activities. Because of this, it is a tool that must be calibrated according to the competencies and skills of the users and the organization (schools, companies, etc.), as well as the indirect users of the process, such as friends and families, since they also represent a source of influence on the learner's perception of the gamification process. In order to achieve long-term success, it always has to be squared from the more general point of view of the center, otherwise, the objectives will be lost in the rest of the contents that have not been gamified.

It must also be said that the creation of a 'gamified system', for example, in a university subject, is not an easy task. There is a risk that the system may end up lowering the level that we want to demand from the students or, and this is even more worrying, that the students end up perceiving that the level of demand has been lowered. For this reason, it will be necessary to be very careful with all the details of the development of the application of gamification, being very clear about the need to be covered and ensuring that all proposals always respond to these needs.

Acknowledgments. To thank CEU San Pablo University for supporting the application of innovative teaching methodologies in the classroom.

To my research group GIMIDyL (Grupo de Investigación en Metodologías de Innovación Docente y Liderazgo) for their support and good work in their research.

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Received: October 15, 2021; Published: October 28, 2021