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Article

Gamification in Science Education: Challenging Disengagement in Socially Deprived Communities

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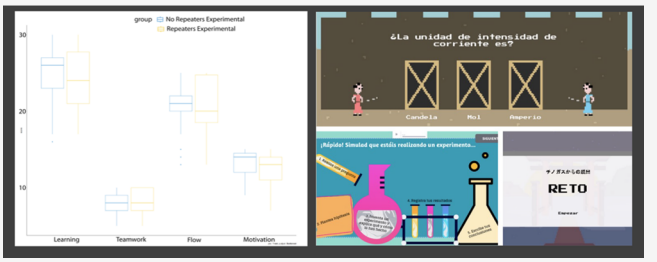
ABSTRACT: This study assesses the effects of an educational gamification program on motivation, engagement, and flow for high school students from socially disadvantaged communities. A quantitative comparison was carried out with pretest−post-test measurements with intervention and control groups. A total of 216 students from two high schools in socially deprived areas participated in the study. The experimental group engaged with a gamified platform for seven 1 h sessions while the control group continued their directive lessons. The results indicate that the experimental group significantly improved its flow, engagement, and motivation score compared to the control group. We concluded by highlighting the usefulness of gamification to motivate socially deprived students in learning scientific subjects.



KEYWORDS: *Engagement, Flow, Gamification, School Failure, Science Education*

INTRODUCTION

Social deprivation consists of personal, familial, social, and economic difficulties that hinder or impede social, emotional, physical, and cognitive development due to poverty. Ref 1 affirms that these difficulties or disadvantages can be perceived in the community to which the person, family, or group belongs; these difficulties can also affect their socialization, basic skills, independence, and communication.[2]

Among students in situations of social deprivation, high levels of disruption can be observed in the classroom and educational center that can interrupt the functioning of the class and affect the ordinary classroom climate.[3] Several authors[4,5] show evidence of the improvement of the classroom climate when the teacher acts as a mediator in the classroom and stimulating activities are offered; the students feel safe and able to function, and social skills are worked on and promoted. When students feel unmotivated in the classroom and have a lower self-concept than their peer group, educational strategies that favor coexistence need to be applied to make them feel like part of the group in particular and of the center in general, favoring their socialization and participation.[6]

Youth born and raised in environments of social deprivation tend to have less academic motivation and develop low expectations regarding their abilities and low levels of emotional self-regulation.[1] This can lead to absenteeism and school failure in secondary education, a stage where most school failure occurs.[7] Even though school failure is attributed to a combination of multiple personal, social, family, and educational factors,[8] new educational strategies are sought from academic centers that motivate students.

To meet students' specific educational support needs in a situation of social deprivation, it is necessary to consider that social exclusion is a multicausal, dynamic, and structural phenomenon[9] that affects the risk of school absenteeism and, consequently, school failure. This risk is particularly increased in scientific subjects due to rejection by students,[10] which may be due to different factors such as having anxiety toward mathematics, considering their capacity for scientific subjects limited,[11] not enjoying the subject, and not having a scientific vocation due to the lack of activities of their interest.[12] Ref 13 states that student participation in mathematics can significantly decrease in secondary school and highlights the importance of motivational, emotional, and social elements that favor performance and learning outcomes. For this reason, the need to propose new learning strategies that improve motivation toward these subjects is evident.

Several recent studies show how educational gamification can be very attractive for young students since they can reach a more outstanding commitment thanks to the game elements[14−17] if the design provides different challenges that

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the students can overcome; dividing the contents into surmountable activities can generate a state of flow where the students enjoy the subject.[18] The most recognized definition of gamification is the use of game design elements in nonplayful contexts.[19] This definition is complemented by others, such as using playful techniques to involve people, motivate action, and solve problems,[20] and gamification as a process whose objective is to increase motivation in an extrinsic and intrinsic way and to have people involved in the task.[14]

The use of playful strategies such as gamification can be an incentive to reduce school failure and improve academic performance. When educational gamification is used, learning is sought without fear of error, which provides a series of challenges that unleashes positive classroom flow and meaningful learning.[21] Educational gamification is identified with the design of playful learning scenarios, where an aesthetic and narrative will be created, and elements of the games will be used (medals, points, levels, avatar, cards, etc.), along with dynamics and mechanics to improve classroom climate and student engagement and enhance their acquisition of curricular content.[22] Achieving high levels of engagement and flow is especially relevant in unmotivated students since it can bring positive feelings toward the educational environment, thus avoiding absenteeism and possible school failure.

Gamification has been linked to different motivational theories. Seligman's positivist psychology model emphasizes each person's positive emotions and personal talents.[23] Gamification enhances the fun perceived by the players/students, which activates their intrinsic motivation.[24] It could also be related to the goal-setting theory,[25] which mentions that, to motivate a person, practical, realistic, and challenging goals must be set and feedback offered to maximize success in their task. In gamification, different dynamics and game mechanics can be implemented so that students see their progress (points, medals, story progression, ...), and playful activities are proposed that pose a challenge for the student.

However, one of the motivational theories with which gamification has been most related is the flow theory of Csíkszentmihályi.[26−30] Flow is a state of total immersion and fusion of action and consciousness that is associated with positive emotional, motivational, and cognitive experiences[31,32]. Flow occurs when the challenge and the necessary skill are high; anxiety when the challenge is beyond the person's capabilities; boredom when skill is greater than the challenge formulated; and apathy when both challenge and skill are below personal average.[33]

In education, the optimal experience that brings each student to a state of flow is one in which they enjoy the activity itself and are immersed in it. To achieve the students' commitment, it is necessary to generate experiences that simultaneously provoke concentration, interest, and enjoyment.[34] Flow has a positive relationship with students' attention and enjoyment, resulting in higher learning.[35]

The introduction of gamification in the classroom has been studied by various authors and bibliographic reviews[36−39] who report different benefits in their practice, such as greater school motivation, autonomy, participation, and academic performance in students. When students perceive learning dynamically and are involved in an attractive topic, using gamification elements, motivation becomes the engine of the process, thus allowing students to achieve positive results in the classroom.

In this research, an educational gamification program has been implemented to improve the academic flow and classroom climate of Physics and Chemistry classes for high school students experiencing social deprivation. This research presents a quasiexperimental longitudinal study in which the following research questions were addressed:

- What impact does educational gamification have on students' academic flow and engagement compared to directive teaching in students in areas of social deprivation?
- How do students perceive their motivation, learning, teamwork, and flow after participating in the gamified program?

METHOD

Participants

The selected sample was students from two public institutes in southern Spain in areas of sociocultural deprivation.

The sample is made up of a total of 216 adolescents between 12 and 15 years old (M = 13.5, SD = 0.82), of which 127 were men (58.8%) and 89 women (41.2%). The control group consisted of 111 participants (M = 13.5, SD = 0.78) with 64 men (57.7%) and 47 women (42.3%). The experimental group consisted of 105 students (M = 13.51, SD = 0.87) with 63 men (60%) and 42 women (40%).

In turn, both the control and experimental groups were divided into two subgroups. The criterion for selecting the subgroups was as follows: having more than 60% repeating students (repeating group) and having less than 60% repeating students (nonrepeating group). Thus, the control group has, on one hand, 88 participants (nonrepeaters) with a mean age of 13.27 (SD = 0.69) years and, on the other hand, 23 students (repeaters) with a mean age of 14.35 (SD = 0.49) years. Regarding the experimental group, there are, on one hand, 63 students with a mean age of 13.46 (SD = 0.4) years and, on the other hand, 42 students with a mean age of 14.38 (SD = 0.62) years.

The sample was accidental and not probabilistic, depending on the accessibility to the centers and the willingness of the management and teaching team to participate in the gamification program. To be eligible in both the experimental and control groups, students had to meet the following criteria: (a) be enrolled in areas of social deprivation and (b) be between 13 and 16 years old.

In the experimental group, teachers were trained on gamification in the classroom and on the specific program to be used. As for the control group, a traditional methodology was carried out where each teacher imparted theoretical knowledge and reinforced the content through review cards.

All students were orally informed about the study, and the data collection procedure was explained. Before data collection, students were informed about the nature of the research and assured of anonymity. The gamification program was integrated into the curricular contents of the Physics and Chemistry subject. This study complied with the recommendations of the American Psychological Association and the Declaration of Helsinki. Ethical approval was obtained from the Research Ethics Committee of the University of Almería (ref. 01/2021).

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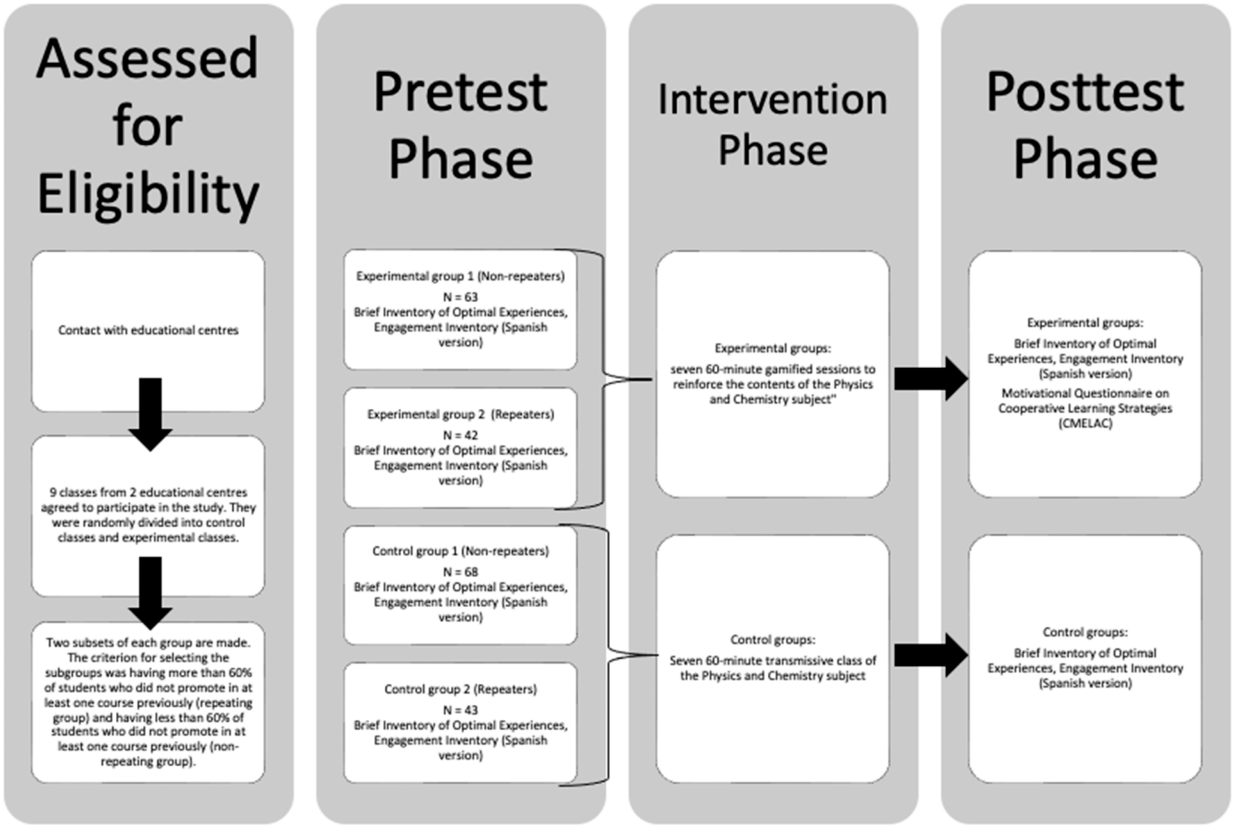

Figure 1. Flowchart of the procedure.

Table 1. Guide on the Implementation of the Escape Room

Name	Description
Front page	As in the series, each of the missions in which they had to participate took place in a different country. In the image of the cover, the country was presented with something representative of the country and the name of this one.
World map	In all the missions in which a world map appears, students must locate the country and click on it to continue.
Video of an episode of Carmen Sandiego	The video of the mission was a video of Carmen Sandiego's series of Nexflix in which she explained curiosities of the country and gives rise to the introduction to the main mission.
Message of the curricular tasks of that mission	After the video, a screen appeared which gave access to the gamification part of this mission. On this screen, the different tasks that could contain this mission appear. Generally, there was a main mission and one or two secondary ones that brought additional rewards.
Rewards menu	The reward panel clearly showed what the reward per task performed would be. From this panel, they can access the mission rubrics that explain in a clear way what the students are expected to do for the mission task to be considered completed.
Main mission (part 1)	The main mission is directly related to the curricular content of the subject. In the example image we teach the changes of state of matter. To teach these contents, different game dynamics were elaborated to work on each one of the contents.
Main mission (part 2)	In this example, the main quest is divided into two parts. At this time, students must participate in a quiz made with the Genially platform on the content of the subject. If they failed, the platform returned them to the beginning of the quiz. This activity was also carried out cooperatively. Once resolved, it gave the final key to unlock V.I.L.E.'s tablet.
Side quest	The side quests are small playful challenges related to the curricular content. For example, a crossword puzzle with words related to the water cycle is displayed.
Final message	When the students have overcome all the proposed challenges, the daily narrative ends. It always ends by mentioning that the students (spies) have helped Carmen Sandiego defeat V.I.L.E..

Procedure

A quasiexperimental longitudinal design was carried out with a prior and subsequent evaluation with a control group to address the research questions. Initially, a previous assessment was conducted to verify that the groups were equivalent in the studied variables. The intervention with the experimental group consisted of seven 60 min gamification sessions to reinforce the contents of the Physics and Chemistry subject in the second year of high school. In contrast, the control group used a traditional methodology through the directive class and the use of the textbook. After the intervention, the same questionnaires were administered during school time (see Figure 1).

Gamification Design

An educational gamification program was designed for the Physics and Chemistry subjects to improve classroom flow, engagement, and classroom climate. It was implemented during the first quarter of the 2020/2021 academic year in 7 sessions. An example of a session is described in Table 1, which shows a learning sequence to work on the content of a topic of

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Figure 2. Example of a mission.

Physics and Chemistry (see Table 4). This sequence has been used for other content, and the material is reusable. It can be requested from the corresponding author.

An MDA framework (mechanics−dynamics−aesthetics) based on game design theory was used:[40]

- Aesthetics: Carmen Sandiego's (Netflix) narrative, fantasy, and challenge.
- Dynamics: Progress, feedback, cooperation, and time trial.
- Mechanics: Missions, challenges, points, badges, and store/prizes.

On an aesthetic level, the narrative used the reboot of "Carmen Sandiego", produced and distributed by Duane Capizzi, Jos Humphrey, and Kenny Park by Netflix in 2019. The protagonist of the animated action series is Carmen Sandiego, a young thief who travels around the world to defeat the criminal organization V.I.L.E. (International League of Villains of Evil).

The pedagogical decision to use this series to energize the narrative had the following reasons: (a) It is a series that can easily connect with the interests of the young audience. (b) The protagonist is a woman, appealing to the need for empowered female referents.[41] (c) In addition to being an action series, it contains educational elements and mentions data of interest from the different countries that are visited in each chapter, which could be related to the missions within gamification.

The dynamics and mechanics were used to seek to promote meaningful learning, which poses surmountable and motivating challenges to the students. Both individual and cooperative missions are proposed related to the Physics and Chemistry curricular content, where Carmen Sandiego has a mission. As part of the spy team, the students must help them carry out the mission (see Figure 2). These missions were projected on the digital board and were designed with the Genial.ly tool. A final mission was developed that consisted of a digital escape room where the students completed a series of puzzles until they managed to defeat V.I.L.E. and finish the narrative.

Considering the prevention, hygiene, and health promotion measures against COVID-19 for educational centers, doors and windows were always kept open to favor ventilation; each student wore a mask and used hydroalcoholic gel before entering the classroom. For cooperative activities, groups were stable and shared ideas from their site, ensuring that the volume was tolerable.

According to a rubric, these missions have a series of points and associated medals that the students can see at the beginning of each mission. With the points obtained, they can buy different prizes in the store. The students agreed upon these awards on the first day of the program to ensure that they were interested. From lowest to highest cost, the rewards were: listening to a song, spending a day without homework or 5 min with their mobile phone in class, having one extra point in an exam, and having one extra point in the final evaluation.

Instruments

- Brief Inventory of Optimal Experiences.[42] The inventory comprises nine items, from which a total score of optimal experience (flow) is obtained in the activity evaluated. The nine items have five response options from Strongly Agree to Strongly Disagree. Cronbach's alpha values are 0.864.
- *Engagement Inventory*.[43] Its version validated in Spanish has been used from an internal consistency analysis where the Cronbach alpha values are higher than 0.80. The scale is made up of 24 items divided into five factors: Affective Engagement (e.g., I feel interested), Behavioral−Compliance (e.g., I listen very carefully), Behavioral−Effortful (e.g., I get really involved in-class activities), Cognitive Engagement (e.g., I think intensely when I take quizzes in this class), and Disengagement

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Table 2. Mean and Standard Deviation of the Groups: No Repeaters Control, Repeaters Control, No Repeaters Experimental, and Repeaters Experimental

	Non-Repeaters Control		Repeaters Control		Non-Repeaters Experimental		Repeaters Experimental	
	M	SD	M	SD	M	SD	M	SD
				Pretest				
Flow	29.41	4.86	29.40	4.92	30.29	4.89	31.63	5.07
Affective motivation	16.78	2.98	16.19	2.98	17.59	3.56	17.35	3.23
Behavioral motivation	16.32	3.12	15.38	2.21	16.69	2.91	15.88	2.37
Attitudinal motivation	16.65	2.75	16.33	3.14	16.30	3.73	16.17	3.37
Cognitive motivation	33.63	7.19	33.00	6.35	34.91	6.29	32.09	4.93
Disengagement	6.13	2.74	6.52	1.64	5.94	2.80	6.84	2.01
				Post-test				
Flow	29.75	5.24	30.51	5.20	34.70	3.64	33.57	5.10
Affective motivation	16.69	2.11	16.09	2.34	19.59	2.03	18.83	2.45
Behavioral motivation	17.22	2.64	15.88	2.86	20.07	2.34	19.79	3
Attitudinal motivation	17.51	2.77	16.33	3.14	20.25	3.03	18.65	4.09
Cognitive motivation	33.72	5.94	32.74	5.16	41.43	6.98	39.88	7.03
Disengagement	7.62	2.90	8.40	2.91	4.73	1.82	5.14	1.47

Table 3. ANOVA Tests with Pretest Scores and ANCOVA Tests with Post-Test Scores As Dependent Variables and Pretest as Covariates and Post Hoc Test[a]

	ANOVA			ANCOVA			
	F	p	η_p^2	F	p	η_p^2	post hoc post-test scores
Flow	2.10	0.101	0.029	44.01	***	0.385	NRE-NRC***/NRE-RC***/RE-NRC***/RE-RC*
Affective motivation	1.89	0.131	0.026	52.23	***	0.423	NRE-NRC***/NRE-RC***/RE-NRC***/RE-RC***
Behavioral motivation	2.17	0.92	0.03	43.36	***	0.381	NRE-NRC***/NRE-RC***/RE-NRC***/RE-RC***
Attitudinal motivation	2.96	0.033	0.04	7.81	***	0.115	NRE-NRC***/NRE-RC***/RE-NRC***/RE-RC***
Cognitive motivation	1.90	0.13	0.26	38.70	***	0.355	NRE-NRC***/NRE-RC***/RE-NRC***/RE-RC***
Disengagement	1.39	0.246	0.019	42.14	***	0.375	NRE-NRC***/NRE-RC***/RE-NRC***/RE-RC***

[a]Note: NRC = Nonrepeating Control, RP = Repeaters Control, NRE = Nonrepeating Experimental, RE = Repeaters Experimental, p = 0.001 (***), p = 0.01 (**), p = 0.05 (*).

(e.g., I just pretend like I am working). Each item begins in the same way: "In this class, ...". The responses to each item are made through a Likert-type scale that ranges from 1 (totally disagree) to 5 (totally agree), except for the items belonging to Cognitive Engagement which range between 1 and 7.

- Motivational questionnaire on cooperative learning strategies (CMELAC).[44] The questionnaire comprises 22 items with five response options from totally agree to totally disagree. The questionnaire is divided into four factors: motivation for the task, learning, teamwork, and flow. The reliability analysis of each factor reaches a Cronbach's alpha score greater than 0.70.

Data Analysis

IBM SPSS v25 was used to calculate the statistical tests. The R Studio ggplot2 package was used to create the graphs.

To determine whether the groups were statistically equal, an ANOVA test was performed with the pretest scores of the variables studied.

To determine whether there were statistical differences between the 4 groups after the intervention, ANCOVA tests were performed with each of the study variables. For these tests, post-test scores were used as the dependent variable and pretest scores as the covariate. If differences were detected in the ANCOVA test, post hoc tests were performed using the Bonferroni adjustment method.

RESULTS

For a better understanding of the analyses, Table 2 shows all the means and standard deviations of the groups that participated in the research.

Before answering the research questions, an ANOVA test was performed on the pretest scores to check whether the groups started from similar scores. The results of these tests are reported in Table 3. As can be seen in this table, no statistically significant differences were found between the participating groups in the pretest scores. It is worth mentioning that although in the variable "Attitudinal motivation" statistically significant differences appeared in the ANOVA when the post hoc tests were carried out, no such differences between groups were detected.

To answer the research questions, an ANCOVA test was performed for each of the variables. The post-test scores were used as the dependent variable, and the pretest scores of each of the study variables were used as covariates.

In Table 3, in the ANCOVA section, the results of the statistical tests were reported, and post hoc tests were added to check between which groups the differences had occurred.

Analyzing the results of the post hoc tests, all the changes occurred between the experimental groups versus the control groups. No statistically significant differences were found within the experimental groups (No Experimental Repeater − Experimental Repeater) or between the control groups (No Control Repeater − Control Repeater). That is to say that all groups started from a statistically similar situation, and after

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the program, both the experimental repeater and nonexperimental repeater groups benefited from the program in the same way as the control group.

We can also extract information based on the size of the effect represented by eta partial square (η_p^2). According to the standard interpretations of this statistic, we can deduce that all effect sizes found are of large magnitude ($\eta_p^2 > 0.14$).

To test whether being a repeating student influences how gamification is perceived, the questionnaire on cooperative learning strategies (CMELAC) was used and compared between the experimental groups. No statistically significant differences were found. In Table 4, the means, standard deviations, and t test results are reported (only the probability is reported).

Table 4. Means, Standard Deviations, and p-Values of the Results of the Student's t Tests of CMELAC in the Control Group after the Intervention and in the Experimental Group after the Intervention

	No Repeaters Experimental		Repeaters Experimental		
	M	SD	M	SD	P
Motivation	13	1.87	12.60	1.82	0.284
Learning	24.9	3.01	25	3.77	0.869
Teamwork	7.92	1.43	7.98	1.64	0.855
Flow	20.7	2.55	20.80	3.44	0.787

In Figure 3, we have plotted the mean scores of the CMELAC factors, and we can see that the results are very similar and that there are no appreciable differences.

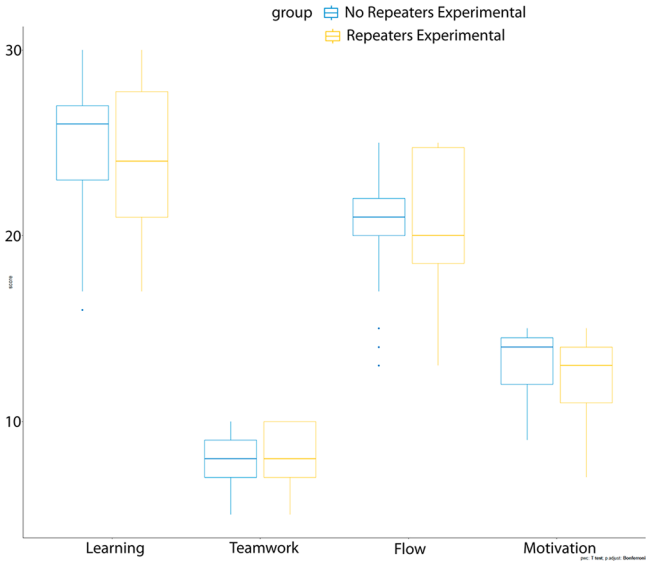

Figure 3. Box-and-whisker graph of the CMELAC questionnaire.

DISCUSSION

This study shows that educational gamification could be an effective strategy to increase classroom flow and engagement since statistically significant differences can be observed in favor of the experimental group, regardless of whether the students have repeated or not; both groups benefit from the gamification program. However, once the statistically significant differences between the experimental groups have been studied, it is observed that the nonrepeating group achieves a more substantial benefit in engagement and classroom climate than the repeating group. These results can be explained due to other factors related to grade repetition, taking into account socioeconomic and family characteristics and other risk factors such as drug use and personal, social, and school maladjustment.[45]

Furthermore, this research confirms that gamification can be used with active learning methodologies such as project learning and cooperative learning. This coincides with other studies that mention that the connection between cooperative learning and gamification allows students to acquire prosocial and collaborative skills and behaviors among their peers.[46] Proposing cooperative activities this academic year was complicated due to COVID-19. Still, it is necessary to devise new strategies to continue to be applied since it improves both motivation and the classroom and socialization climate,[47,48] aspects already diminished due to the psychological, social, and educational impact that the pandemic has produced.[49]

Finally, the CMELAC results show that the students have positively valued the elements of the gamification program and have enjoyed working as a team. The selection of aesthetics, dynamics, and mechanics is essential for students to find the program fun, motivating, and valuable for their learning. It is emphasized that playful elements such as narrative and challenges are intrinsically motivating elements.[50,51]

Although this study shows promising results in the implementation of gamification programs for secondary school students in a situation of social deprivation as a tool to improve motivation in scientific subjects, there are several limitations that we must recognize. In the first place, the sampling was not random since the selection was influenced by the voluntary nature of the implementation of the program. Another limitation was that the program was applied in one quarter, so the long-term effects of gamification could not be determined. The theoretical framework on gamification in students with social deprivation is limited due to the scarcity of research on educational gamification programs that implement them with this group. Finally, this program has not considered the participation of families due to the COVID-19 pandemic; the scientific literature confirms the importance of family involvement in the training of their children and the close relationship between teachers and families.[52] Future research could focus on longitudinal studies of longer duration with these students, carrying out the evaluation again several months after applying the program to check if the effect on the variables studied lasts over time, studies where gamification programs that use different playful elements to observe the differences in the motivation of the students, and studies where the family is involved in various gamified activities to assess whether their participation benefits the school performance of their children.

CONCLUSIONS

In this research, an educational gamification program has been designed, implemented, and evaluated in a center in an area of social deprivation to promote the motivation of this type of student. Even though social deprivation is multifactorial, educational centers are responsible for assessing methodologies that encourage student involvement to reduce school failure and drop-out. This research suggests that using playful learning strategies with this type of student can positively influence

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their motivation, participation, and interaction among peers, with the same effectiveness for repeated students.

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Notes

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