Mixed gamification with virtual tools modify poor school performance

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ABSTRACT

Currently, the use of gamifiers as teaching tools in virtuality is present due to the digital education that is developed in Latin America. The objective was to determine the effects of two methodologies: i) Mixed gamification; and ii) Usefulness of virtual teaching tools, in the cognitive processes of poor school performance. The methodology was experimental, quantitative. The evaluation was carried out on 150 Spanish-speaking schoolchildren, divided into three comparison groups (8.5 years of age ±0.4). They underwent 40 learning sessions with the D-S-F methodology (dynamics, strategy, feedback). The validated instruments were three performance tests on the areas of mathematics, science and communication. Significant results were obtained in cognitive processes from the activities designed with mixed gamification, although the effects were not decisive in the area of communication. It is concluded that gamification reduces low performance to raise cognitive processes for logical reasoning, cognitive deduction in mathematics, skills to generate hypotheses in science; and those of reading and oral expression. It is suggested to develop experiments with variables that include a digital evaluation of text writing, to avoid the limitations presented in this research.

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1. INTRODUCTION

The most used tools in the initial and transition period of the pandemic by Peruvian teachers are Kahoot!, Mentimeter, Mural.ly, Google Jamboard, since they consider that the development of learning becomes more comfortable and participatory in subjects. This began from the approach of the Supreme Decrees that were formulated by the Government for the dictation of classes from the use of television and the Internet in the Peruvian nation between 2020 and 2021. Given this, other effects have appeared in younger students, especially in primary education, who learn mathematics as well as reading. However, another important aspect is the emotional one, in which until now they have had progressive effects. This deficiency had already been triggered since the Third Regional Comparative and Explanatory Study (TERCE) evaluation period [1], since in this period students from Latin American countries were below average in both reading, mathematics and science. Therefore, some research has also revealed that the sociocultural effects of the family also affect this performance, especially in the development of collaborative or personal tasks [2]–[4]. It is for this reason that the study seeks to identify whether the use of virtual education platforms and gamification as a form of game can have effects on cognition in students with certain school performance after having gone through two years of the pandemic in Peru.

In this sense, these platforms have positive effects on student motivation, allowing the teacher to consider developing macro-achievements with increasingly complex learning objectives [5]–[7]. The participatory exchange of virtual tools as a means of gamification of complex tasks develops greater receptive capacity and benefits on academic affection towards successful performance according to the area in which the student feels more attracted [8]–[11]. Thus, gamification differs from the use of technological materials for education as it is understood as the use of game elements to imitate them in teaching, generate sports and practical environments on the central objective of the student. Thus, both individualistic and collaborative competition are promoted, establishing an imitative modality of both video games and alternative games [12].

Gamification as a means of developing school and university learning has focused on the study of performance in mathematics, as well as mathematical reasoning [12], [13], reading, regulation emotional stress from academic stress [14], [15], and in academic well-being [16], [17], since its effects have managed to reduce the slowdown of work processes in memory, as well as the reduction of the ratio for problem solving; as well as in critical socio-geographical work [18]. On the other hand, teaching based on traditional games can have a positive effect to develop attentional variables such as dynamism and the development of constructive learning processes, since collaboration between peers can also be beneficial in curricular development. However, there is little evidence to include gamified games from the use of other elements such as virtual environments, video games or interactive mobile tools, which is conceived as a form of mixed development as a form of massive gamification in the game virtual learning.

As for theoretical studies based on the constructionist approach, it can be argued that learning is linked to components such as deduction, abstraction, in addition to dynamism or cognitive dynamics [19], [20], since there is a relationship between the understanding of information, procedures and instructions; and this can be strengthened due to the use of prior knowledge used by the participants in some group intervention [21], [22]. Cooperation through technological means can contribute to the use of this prior knowledge, reduce the derisory conditions of understanding the information to increase the positive conditions for proposing solutions.

According to the approaches of authors who indicate that mathematical practice based on didactic elements that allow personal and individual cognitive interaction [23]–[27], as well such as conversation, debate with the teacher and with playmates, didactic questioning, and semiotic development for children's learning [28]–[30]. Apparently, these evidences allow us to understand that these teaching characteristics would dissipate cumbersome executive functions to solve more complex mathematics, and reduce cognitive overload in learning processes that require more time and space to be able to respond better to mathematical problems [24], [28]–[31]. From what has been reviewed, it is understood that all mathematical learning that is already complex and is a sample of the most influential learning in the Latin American population, marked as one of the problems that concern educational quality. Therefore, in this experience we compromise low-level learning and its responses before the effects of other variables that include the use of digital resources, the quality of software support on the teacher's pedagogical strategies. The results of the mixed application of virtual resources in distance learning can compensate for the appearance of exogenous variables that prevent fluid understanding of information, proposals for solving problems and reflection on learning.

Given this review, the study seeks to investigate the effects of using technological tools that are usually applied in virtual education by teachers, and which we will call formal (Kahoot!, Mentimeter, and Google Jamboard), in combination with the use of some of the technologies and games that male and female use for leisure activities (Super Nintendo, Xbox, PS1, PS2, …, PS5); as influences in the development of cognitive abilities in situations of low academic performance. In this sense, after the relevance of the negative results that indicate the limitations of the unique use of gamifiers included in the classroom, there is also a need for motivators based on serious games in classroom interaction, as well as games for fun. This has not yet been fully found in the current literature, more only techniques applied in isolation. For this reason, this experience of multiple didactics is applied in contexts of vulnerability in which there are problems learning mathematics, communication, as well as science and technology themes in primary education.

The applied method is the hypothetical deductive one, of an experimental type, with a proposal compared through two didactic modalities as opposed to another traditional learning experience. The proposal sought to outline the research based on pure gamification and cognitive gamification [12], [13], [24], [30], [32], in order to establish better abilities to operate mathematically, develop problems based on reasoning, the analysis of the environment, as well as the achievement of skills for expressiveness and communicative reading. Thus, this proposal translates into the application of the DSF technique (dynamics, strategy, feedback), for motivation, teaching with parallel gamification, in turn, that the student achieves the knowledge of what is learned to do and monitor their own learning through critical play.

The research raises the question: do the effects of the mixed use of technologies with serious games and games for leisure differ from the usefulness of unified gamifiers on the abilities to learn in cognitive areas in students with low performance? Thus, the hypothesis focuses on the fact that the effects of mixed gamification will be more powerful, compared to the single application of virtual tools on basic cognitive learning processes in students with low school performance. In this sense, the effects of both gamification styles are verified in a mixed pedagogical execution in controlled learning environments.

2. RESEARCH METHOD

2.1. Participants

The research is of experimental design, with three comparison groups and pre-test and post-test. The sample consisted of 150 subjects, chosen through a simple random sampling from a total of eight public schools of Basic Education. These belonged to the northern area of Lima and Callao. In this sense, this area was addressed due to the last survey applied to assess reading, mathematics and science skills by the Ministry of Education of Peru. After the personal investigation in these institutions, it was possible to discriminate that these schools were located in housing associations and human settlements marked as vulnerable contexts, whose parents came from a very poor economic segment. These were located in type C or D (poor and very poor), as well as their homes were in social problems, not fully attended by the public sector (robbery, neighborhood gangs, and dissidence).

The distribution was 50 students per group. The students were in cycle IV of Regular Basic Education when the study was carried out (M=8.5 years of age; SD=0.4). Regarding gender, the female gender prevailed in the first group and in the control group (EG1=72%; EG2=60%; CG=55%). All subjects were included in the initial population based on criteria: i) present performance at achievement level C in the areas of mathematics, science and communication (vigesimal grade <11); ii) be located in the range of 8 to 10 years of age; iii) demonstrate stable conduct regarding their behavior in the last six months before the initial evaluation; iv) regular attendance during the last two months before the approach; v) belong to a public educational institution. All participated through the permission of their parents through informed consent management.

2.2. Materials and procedure

For the evaluation, three instruments were developed according to the cognitive area for the purposes of the experiment, namely math test, science test, and communication test. Each test presented a total of 30 open-response questions. All were structured with ordinal-type ratings (good=2 points; regular=1 point; bad/no answer=0 points). The standardization of these scores was carried out to provide a greater range of response to those evaluated, in order to assess both their procedures and their responses. The components evaluated in each area corresponded mostly to a cognitive approach, trying to adapt to the contents of the performances that the students developed in their usual educational system as shown in Table 1. The tests underwent content review with five expert judges in the respective areas. For this procedure, three teachers were chosen by specialty and two professors of research methodology for all the instruments, for which eleven professionals finally participated, who provided total acceptability after the counseling process on the criteria with which each instrument was evaluated: relevance; linguistic adaptation; and relationship.

Table 1. Components and reliability of mathematics, science and communication instruments

Performance test	Components	Reliability	Total reliability
Mathematics	Logic reasoning	0.89	0.90
	Calculation and operations	0.91	
	Problem resolution	0.89	
Sciences	Observation	0.91	0.91
	Hypothesis	0.89	
	Deduction and verification	0.93	
Communication	Reading and understanding	0.92	0.92
	Oral expression	0.93	
	Text writing	0.91	

On the other hand, a pilot plan was also developed with 100 students from cycle IV of educational institutions belonging to the same network of educational institutions involved, so that through the corresponding statistical processes, the indices were obtained with which it was accepted that the evaluation tests and their components presented reliability for their application in the research sample. This decision was made in order to be able to relate the cognitive characteristics of the students in the sample with others who presented similarities in their performance. Without neglecting the consideration that they should be standard tests to which subjects with low performance responded in the same way, which required including students with similar performance in this pilot test. The qualitative data of the subjects with high and low performance were compared to determine if the tests were compatible with the subjects of the groups to be studied, these being positive for that purpose.

Regarding the procedure, it was decided to organize 40 learning sessions that integrated the use of traditional virtual tools and video games. For the initial experimental group (EG1) technological tools were used such as: Kahoot!, Mentimeter, Mura.ly, Google Jamboard; and the introduction of video games used on a PS4 console shown in Figure 1. In this sense, the EG1 group stipulated a DSF-type strategy (dynamics, strategy, feedback), which allowed each class to allow the use of virtual tools for a period of 5 to 10 minutes. Then, in strategies stage, the thematic classes of the area were developed, accompanied by the use of video games according to their needs. In this sense, cognitive activities were gamified using the elements of the video games themselves (characters, scores, cards, and medals). Finally, the feedback stage was developed for 20 to 30 minutes, in which reinforcements of two types were provided, either by the teacher or by other classmates in the group competition work.

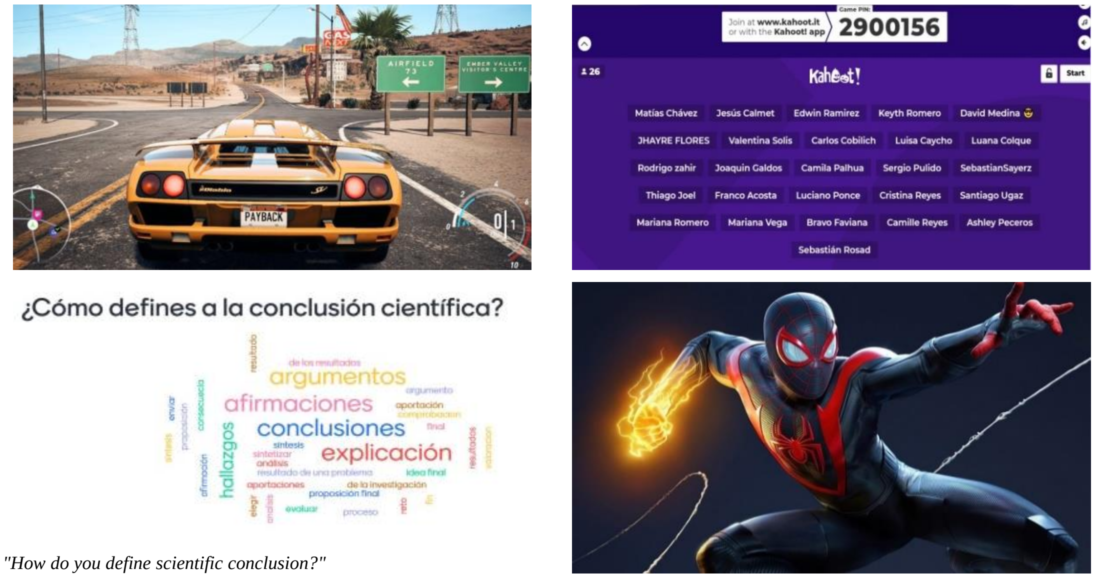


Figure 1. Exemplification of tools and videogames used in the experimentation groups

In the EG2 group, only video games were used in an additional 40 learning sessions. In this case, the dynamics and strategy stages were unified to intersperse video games accompanying the group work on the theme to be developed per session; as well as the development of exercises on the three educational themes. Here, the feedback system had to be extended up to 40 minutes in order to prevent the effects of boredom and calm from affecting the development of each class, since they could be repetitive. On the other hand, in the CG group, standard learning sessions were developed, with beginning, process and end phases; which involved 5-minute feedback. These phases obeyed the general training guidelines of the Peruvian educational system. At the end of the study and collecting the post-test evaluation data, the EG1 program was replicated in the EG2 and in the CG in order to standardize the capacities, motivations and attitudes in the groups, obeying the criterion of justice as an ethical part of the investigation.

3. RESULTS AND DISCUSSION

3.1. Comparison in the mathematical, science and communication variables

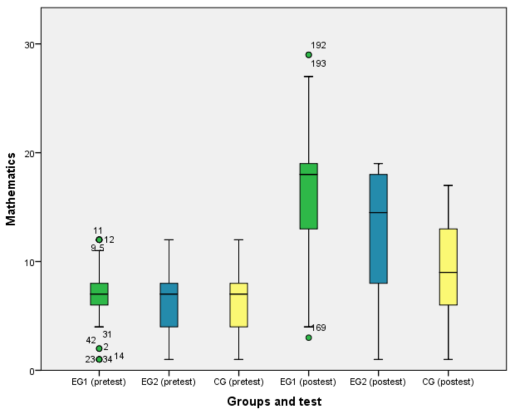
On the data obtained, the comparisons were made from an ANOVA and Tukey test. In turn, the independent effects in the EG1 and EG2 groups were corroborated with a Dunnett analysis. Regarding the pretest measurement, the cognitive balance was corroborated in the subjects of the samples EG1, EG2, and CG; since the values indicated for the ANOVA test were not significant with values less than 1% ($p>0.01$) as seen in Table 2.

Table 2. ANOVA test in mathematics, science, and communication

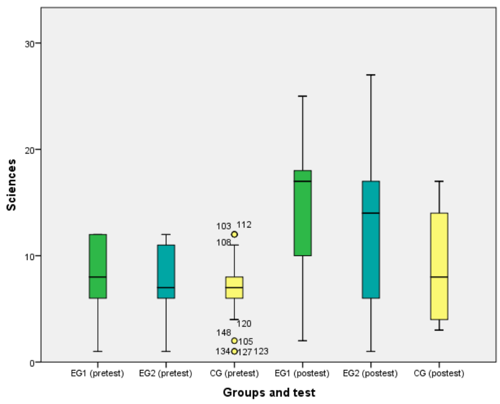
Performance test			Sum of squares	df	Arithmetic average	F	Sig.
Mathematics	Pre-test	Bg	9.760	2	4.880	.477	.622
		Wg	1505.200	147	10.239		
	Post-test	Bg	1282.720	2	641.360	23.375	.000
		Wg	4033.280	147	27.437		
Science	Pre-test	Bg	17.213	2	8.607	.727	.485
		Wg	1739.860	147	11.836		
	Post-test	Bg	665.760	2	332.880	9.139	.000
		Wg	5354.240	147	36.423		
Communication	Pre-test	Bg	23.680	2	11.840	.862	.425
		Wg	2019.820	147	13.740		
	Post-test	Bg	431.293	2	215.647	14.340	.000
		Wg	2210.680	147	15.039		

Note: Bg=between groups; Wg=within groups; Df=degrees of freedom

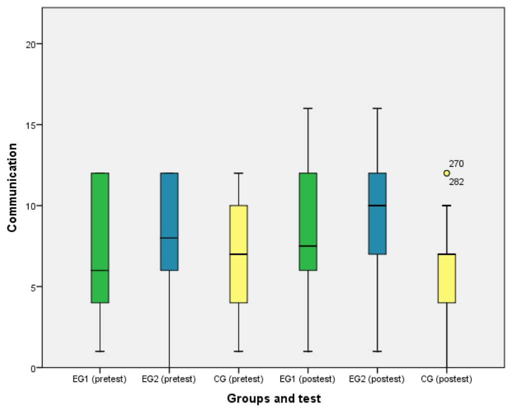
Regarding the post-test measurement in the variables analyzed after the application of mixed gamification and the use of technological tools, values were found that corroborated the intergroup difference in all variables ($p<0.01$). Whereas, from what is observed in Table 2, it can be considered that the effects generated in the groups EG1, EG2 differ from those of the CG. Although, Figure 2 shows values outside the quartiles obtained in the EG1 group in the pretest measurement (2, 9.5, 11, 12…31, 32…), as well as in the posttest measurement (169, 192, 193). For the comparison of the mathematics variable, values with the same characteristics are also observed in the CG data in the science pretest measurement (103, 108, 112...), as well as in the communication posttest measurement (270, 282); it was decided to verify the data with the t-Dunnett statistic. Regarding a general analysis of low-performance cognitive processes, significant data were obtained with changes in the EG1 and EG2 groups (I-J=16.750; sig.=.000; $p<0.01$). Although Tukey's comparative test assumed that the effects were of greater potential in those received in EG1, this was also corroborated in a Dunnett's test (Hsd=11.71; $D_{(I-J)}<0.05$).



(a)



(b)



(c)

Figure 2. Comparison of scores in (a) mathematics, (b) science, and (c) communication

In a first analysis on the mathematical variable in the post-test measurement as seen in Figure 2, the effect value of mixed gamification presented a better mean difference, being favorable to EG1 (I-J=7.160; sig.=.000; p<0. 01). Tukey's Hsd tests and Dunnett's value also confirmed better effects in the EG1 group (Hsd=6.82, $D_{(I-J)}<0.05$). Whereas, it can be accepted that the independent variables had effects on mathematics, differentiating the playful influences in the EG1 and EG2 groups from those controlled in the CG. However, subsequent verifications reported differentiated and greater effects of mixed gamification, this being significant, and better than the use of technological tools.

Regarding the second report on the science variable, the values obtained from the post-test measurement reported significant differences for the effects of mixed gamification in EG1, without the effects of EG2 being discriminated from this (I-J=5.160; sig.=.000, p<0.01). In other words, the data did not allow corroborating comparisons between the effects of the independent variables to decide the best. However, this was also confirmed by Tukey's test and Dunnett's value (Hsd=7.82; $D_{(I-J)}<0.05$). In this case, it can be argued that although the effects of both influence variables were significant, the only recognizable effect in science was that of mixed gamification.

According to what was found in the data of the communication variable in the post-test measurement, it was obtained that the mean difference was significant and favorable for mixed gamification in GE1, although it was minimal compared to what was obtained in the comparison EG2-CG (I-J=3.720, sig.=.000, p<0.01). The subsequent tests presented values of greater effect in the EG1 group than in the GE2 (Hsd=7.86; $D_{(I-J)}<0.05$). From all this it can be deduced that the mixed gamification and the use of digital tools influenced the development of communication learning, however, the mixed gamification presented greater effects than the sole use of digital tools for dynamization in the class.

Due to the results, it can be accepted that the low performance of the students has been reduced due to the independent variables immersed in the learning of the subjects of EG1 and EG2, since the mixed gamification which included the use of gamified elements of videogames in a learning session as well as the use of virtual didactic tools, were more significant in the development of the cognitive processes of children with low performance (EG1), compared to the effects of the sole use of virtual tools in schoolchildren with similar condition (EG2). Whereas, it is acceptable that both groups have developed higher level academic cognitive skills when compared to the level of skills that these subjects should develop in the Peruvian national educational system.

The D-S-F structure involved in the learning sessions allowed the development of better motivational effects towards learning, as well as game dynamics aimed at the initiation of increasingly effective cognitive results as the activity program progressed applied in EG1. For this reason, it is accepted that mixed gamification includes the motivational effects extrinsic to learning as well as the dynamic effects on the cooperative or personal activity of the subjects involved in this group. Thus, similarities are found with other studies in which greater selective reception and attention to information is caused by the student, especially when virtual games are collaborative [9], [10]. It should not be ignored that educational tools (Kahoot! Mentimeter, Quizziz) can encourage the achievement of more specific participatory objectives than the gamified games themselves, but here it has been revealed that the companion of phases D and S in the methodology from the use of the elements of the video game have acted as a dissipator of the cognitive recharge in each area of learning. This was determined by other investigations that reveal that the playful power of these factors can be elemental to obtain greater attraction and sustained attention without the need for the game to present a learning objective, more only a personal leisure objective [6]–[8].

In this sense, it can be added that although it is true, the effects of the use of video game content in class may have amortized other variables such as distraction, false motivation, lack of cooperation, the progress made by the students in the group is remarkable. that enjoyed the unique use of virtual tools, the balanced results at the beginning (pre-test evaluation) compared to the final scores obtained (post-test evaluation), showed that these effects also developed certain cognitive abilities compared to the control group, in whose participants it was also applied the F phase (feedback). Apparently, this activity had greater strength in the subjects of EG1 than in EG2, and even the CG, which corroborates that the use of playful tools must be cooperative in learning rather than individualistic [7], due to the fact that the intention to compete in groups can support collaborative traits between members, as has been reported in research that ensures that they are a form of stress regulator, increasing psychological well-being to learn [7], [14], [16].

3.2. Dimensional comparison of mathematics, science, and communication

Regarding the pre-test measurement on the dimensions of logical reasoning, calculation and operations, and problem solving, equality was found between the scores of the three participating groups, so that each significance exceeded the allowed error value of 1%, describe in Table 3. This has allowed us to argue that the subjects of all the groups began the experiment with a certain average equality, before executing the treatment activities.

Regarding the post-test measurement, significant differences were found in the post-test measurement in all cases as seen in Table 3. The mean differences with the most powerful intergroup effects for mixed gamification (EG1) were obtained in the logical reasoning dimensions as well as in calculation and operations ($I\text{-}J_{(LR)}$=2.700; $I\text{-}J_{(CO)}$=2.840; sig.=.000, p<0.01). Tukey's tests were homologated with Dunnett's ($Hsd_{(LR)}$=2.00; $Hsd_{(CO)}$=2.22; $D_{(I\text{-}J)}$<0.05). On the other hand, differences in favor of the sole use of technological tools were reported in the problem-solving dimension of the EG2 (I-J=1.620; sig.=.000; p<0.05). In the post-hoc tests, the improvements were verified in their favor (Hsd=2.52; $D_{(I\text{-}J)}$<0.05). Whereas, it was accepted that the use of virtual teaching resources had a better effect than mixed gamification on problem solving in the study participants.

Table 3. ANOVA test of the components in mathematics

Components			Sum of squares	df	Quadratic mean	F	Sig.
Logic reasoning	Pre-test	Bg	.653	2	.327	.271	.763
		Wg	177.220	147	1.206		
	Post-test	Bg	183.720	2	91.860	18.010	.000
		Wg	749.780	147	5.101		
Calculation and operations	Pre-test	Bg	2.173	2	1.087	.537	.586
		Wg	297.400	147	2.023		
	Post-test	Bg	215.293	2	107.647	27.054	.000
		Wg	584.900	147	3.979		
Problem resolution	Pre-test	Bg	.893	2	.447	.152	.860
		Wg	433.300	147	2.948		
	Post-test	Bg	80.573	2	40.287	8.165	.000
		Wg	725.320	147	4.934		

Note: Bg=between groups; Wg=within groups; Df=degrees of freedom

The results in the science dimensions presented statistical balance on the scores obtained from the pretest evaluation, shown in Table 4, which could be verified in the observation, hypothesis dimensions; deduction and comparison with indices greater than 1%. Regarding the post-test evaluation, the differences were significant in the observation dimensions with a higher effect value for the EG1 subjects (I-J=1.890; sig.=.000; p<0.01). These values were also corroborated in posttest indices (Hsd=2.21, $D_{(I\text{-}J)}$<0.05). Although, for the hypothesis dimension, the ANOVA values were significant in the inter-group differences in the post-test measurement, differentiating effects of the methodologies executed in EG1 and EG2 were not corroborated, with the Tukey and Dunnett differences not being significant for this case. On the other hand, as can be seen in Table 4, and according to the ANOVA values in the deduction and verification dimension, this did not undergo significant changes, as confirmed by the mean difference data (I-J=0.561; p>0.01). Therefore, subsequent tests provided a similar diagnosis. In other words, mixed gamification and the use of technological tools did not modify cognition in the subjects of the compared groups, with the scores of EG1 and EG2 being very similar to those obtained from the CG.

Table 4. ANOVA test of the components in science

Components			Sum of squares	df	Quadratic mean	F	Sig.
Observation	Pre-test	Bg	2.333	2	1.167	.691	.503
		Wg	248.260	147	1.689		
	Pos-test	Bg	35.293	2	17.647	4.900	.009
		Wg	529.400	147	3.601		
Hypothesis	Pre-test	Bg	4.013	2	2.007	1.116	.330
		Wg	264.360	147	1.798		
	Pos-test	Bg	219.053	2	109.527	13.906	.000
		Wg	1157.780	147	7.876		
Deduction and verification	Pre-test	Bg	.573	2	.287	.111	.895
		Wg	378.120	147	2.572		
	Pos-test	Bg	28.120	2	14.060	2.141	.121
		Wg	945.853	144	6.568		

Note: Bg=between groups; Wg=within groups; Df=degrees of freedom

Regarding the dimensions of communication, they were found to be equitable in the scores obtained by the participants of the EG1, EG2 and CG groups before receiving the mixed gamification activities and the use of virtual tools; therefore, it was found that the cognition observed from the communication area presented initial stability. Due to the post-test data, the reading and comprehension dimension showed changes in the post-test measurement with values less than 1% significance. A posteriori analysis allowed us to establish that the effects of the virtual tools of the EG2 were greater than those produced in the first group (I-J=1.140; sig.=.000; $p<0.05$). Tukey's test showed that the strategies carried out with this technique presented better poise in the members of the EG2 compared to the mixed gamification (Hsd=2.29; $D_{(I-J)}<0.05$). Regarding the values reported in oral expression, significant data were found that demonstrated the difference with an index of less than 5%, which was verified in the difference of means favorable to the first group EG1 (I-J=2.540; sig.=.000, $p<0.01$); which was determined in turn, in the tests of compared effects (Hsd=2.84; $D_{(I-J)}<0.05$). Regarding the writing component of the text, the differences were not significant, the value obtained being greater than that determined as error, both in the ANOVA measures, as well as in the posterior discriminant tests. The details are described in Table 5.

Table 5. ANOVA test of the components in communication

Components			Sum of squares	df	Quadratic mean	F	Sig.
Reading and understanding	Pre-test	Bg	2.340	2	1.170	.606	.547
		Wg	281.700	146	1.929		
	Post-test	Bg	39.853	2	19.927	9.241	.000
		Wg	316.980	147	2.156		
Oral expression	Pre-test	Bg	8.667	2	4.334	2.733	.068
		Wg	231.534	146	1.586		
	Post-test	Bg	177.160	2	88.580	28.873	.000
		Wg	450.980	147	3.068		
Text writing	Pre-test	Bg	11.723	2	5.862	2.032	.135
		Wg	421.230	146	2.885		
	Post-test	Bg	6.493	2	3.247	1.054	.351
		Wg	452.840	147	3.081		

Note: Bg=between groups; Wg=within groups; Df=degrees of freedom

After obtaining the specific results, it was possible to verify the statistical balance between the scores of the participating groups (EG1, EG2, CG) in the three learning areas, for which no significant differences were obtained, this helped to discriminate whether the effects of the independent variables were decisive without obeying external factors in the process. Thus, the low performance in mathematics was reduced so that the increase in cognitive processes in this area develops said academic performance, the contribution of mixed gamification (EG1) being more impressive than the use of virtual didactic tools (EG2). In this case, variables that hindered mathematical reasoning, the use of mathematical information and the verification of the results of the problems were reduced, being more effective after receiving the effects of both methodologies. This is consistent with other studies that accept that the effects of gamification allow the opening of reasoning through the search for mathematical objectives to learn [12], [13], [26], [27], although it must be taken into account that the phases of mathematical teaching were less distracting with the use of game elements, which is usually a problem in gamified teaching [13], [16], [24], [25], [31], [32]. However, this study contributed to recognizing that the mixed elements of the serious game and the leisure game cause more effective mathematical learning profiles if it is accompanied by both methodologies, rather than individualizing them.

Additionally, it can be argued that after the effects of reasoning and the search for information, it has increased in favor of the game, in some cases where students used to have problems effectively processing information [29], [30], or in others, in which low-achieving subjects can usually demonstrate abilities to reflect on their own mistakes [24], [28], [30]. This is something that happens in classes with paradigms that only stay in the constructivist approach, without attending to the new tendencies of the connectivity and social constructionist approach; even more so in a period where virtual interrelationships can support this point.

On the other hand, it is contradictory that the scores obtained in the skills of deduction and verification as part of learning in science, have not allowed to verify the differential effects between methodologies with respect to the control group, nor has it been possible to attribute the changes in the cognitive processes of this part since there were no significant differences. Although other studies related to the use of information declared that the use of instructions accompanying the use of knowledge in group interaction contributes to the development of complex cognitive processes [19], [20]. It is important to state that cooperative strategies were developed for this area in this research, but apparently, they were not sufficient both in number and composition of strategic phases for both the subjects of EG1 and group EG2. All this was different in the observation skill, since the EG1 students developed it due to the mixed gamification. However, the differences in the hypothesis ability were significant, without obtaining scores that allow differentiating the effects of superiority of the methodologies. It can be accepted that these last dimensions described were developed thanks to the effects of mixed gamification and virtual tools, which has been found in studies that claim that playful teaching can reduce the obstacles to using working memory and memory a long term from prior knowledge [17], [18].

Regarding the development of cognitive processes on the communication variable, the participants of the three groups involved showed similar scores before starting the experiment. However, significant progress was made in the reading and comprehension components, and oral expression. However, it is necessary to point out that the effects of the single use of virtual tools were more prevalent in the development of reading and comprehension (EG2) than the use of mixed gamification (EG1). The results were inverse in the development of oral expression, in contrast to which mixed gamification prevailed. Here it can be argued that students in the second group felt more excited to participate in reading and text comprehension practices, which is consistent with studies that found success in the performance of subjects who developed greater academic affection [10], [11]. Thus, in this research, the students who interacted with tools such as: Kahoot! Mura.ly, and others developed abilities to read texts comprehensively by using only these tools in the D-S-F format sessions. On the other hand, individuals with greater interaction with imitations of video games in class, participation with characters of these contents and the use of virtual tools managed to develop their oral expression with greater fluency and clarity, thanks to the receptive capacity that mixed gamification presented in the EG1 [5], [11].

Finally, the writing dimension of the text presented similar scores in the three groups in the post-test evaluation. This was more of a limitation than a result, since it is known that writing performance in this context has usually been low due to the effects of the pandemic on students who developed virtual education for two years. In this sense, it is important to develop further studies with direct gamification in writing in students with the characteristics of this research. This also involves variables such as parental support and curriculum development [2], [3], since some evidence indicates that these have been one of the weaknesses in evaluations at the educational level [1], even before the appearance of the pandemic. Finally, the use of digital tools is necessary to evaluate writing considering students as digital citizens, which can contribute to the adaptation of the school curriculum due to the current professional profile that is requested in the post-school competition.

4. CONCLUSION

In conclusion, the effects of mixed gamification were positive in the performance of the students compared to the performance of those who worked with traditional virtual tools. It can be concluded that this type of gamification increased the performance of cognitive processes for logical reasoning, calculation and operations. Regarding problem solving, virtual tools were more significant; as well as what happened with the reading and comprehension components of the communication area, and the observation capacities of the science area. However, the effects were not significantly differentiable in some components of the area of science and communication, so deduction, proof in science and writing presented similar effects in the compared groups. Regarding the experimental methodology, the strategies based on the D-S-F structure (dynamics, strategy, feedback) with the use of video games were significant in the development of performance. Given the results obtained, it is suggested to implement a type of gamified feedback to this methodology applied to subjects compared by two types of special abilities: talented and beginners. In turn, consider their socioeconomic origin to make comparisons with subjects with similar characteristics.

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