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Evaluation of logical-mathematical skills in preschool students through digital gamification in Santo Domingo, Ecuador

Evaluación de habilidades lógico-matemáticas en estudiantes de preescolar a través de la gamificación digital en Santo Domingo, Ecuador

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Resumen

Las aplicaciones móviles y las Tecnologías de la Información y Comunicación (TIC) son herramientas ampliamente utilizadas en diversos sectores como el empresarial, salud y educación, en este último, las aplicaciones móviles poseen un rol importante para los métodos de enseñanza-aprendizaje. En el Ecuador en 2021, se registró bajo niveles de conocimientos adquiridos en el enfoque lógico-matemático en estudiantes de 3 a 10 años, por lo que, se requiere innovar en métodos de enseñanza-aprendizaje eficaces para estudiantes a nivel preescolar. El objetivo del estudio fue evaluar a estudiantes de nivel preescolar mediante una aplicación móvil diseñada en base a técnicas de gamificación para el mejoramiento de destrezas lógico-matemáticas. Para este estudio, se evaluó los objetivos de aprendizaje estandarizados por el Ministerio de Educación del Ecuador (MINEDUC). En los resultados obtenidos, se determinó que un grupo de estudiantes se encuentra en una etapa de inicio para adquirir destrezas para lograr el conocimiento y otro en proceso de adquirir conocimientos. Se concluye que la gamificación es una alternativa para el mejoramiento de métodos de enseñanza-aprendizaje y un mecanismo óptimo para la aplicación de esta son los dispositivos móviles y las TIC.

Palabras clave: Gamificación, estudiantes, aplicación móvil, destrezas.

Abstract

Mobile applications and Information and Communication Technologies (ICT) are widely used tools in various sectors such as business, health, and education, in the latter, mobile applications have an important role for teaching-learning methods. In Ecuador in 2021, there were low levels of acquired knowledge in the logical-mathematical approach in students from 3 to 10 years old, so it is required to innovate in effective teaching-learning methods for students at preschool level. The objective of the study was to evaluate preschool students through a mobile application designed based on gamification techniques for the improvement of logical-mathematical skills. For this study, the learning objectives standardized by the Ministry of Education of Ecuador (MINEDUC) were evaluated. In the results obtained, it was determined that a group of students is in a beginning stage to acquire skills to achieve knowledge and another in the process of acquiring knowledge. It is concluded that gamification is an alternative for the improvement of teaching-learning methods and an optimal mechanism for its application are mobile devices and ICT.

Keywords: Gamification, students, mobile app, skills.

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1. Introduction

Mobile devices are all elements of small size with multiple processing capabilities, memory, and internet connection, they are designed for specific functions and their main feature is mobility. Operating systems are those sets of low-level programs that allow the abstraction of the properties of the specific hardware of the mobile device and provide services to the mobile applications running on it (Carpenter et al., 2021; Pérez Tamayo, 2022).

According to (John Lemay et al., 2021) 44 % of users prefer the use of Android, 53 % use iOS, and barely 3 % use other operating systems. In Europe, 91,20 % use Android, while 8.30 % use iOS and only 0,50 % use other operating systems. The technological revolution, currently, has allowed the use of mobile devices in education to be of relevance for the improvement of skills and knowledge, similar results are reported in Latin America, considering the use of different operating systems (Childers et al., 2023).

M-Learning is defined as the educational modality that facilitates the construction of knowledge and development of skills autonomously through the Internet. For the development of mobile applications for educational purposes, using gamification, the following factors are considered: permissions, licenses, consents, minors, user rights, functionalities, terms of use, information, and advertising (Kärchner et al., 2022).

Gamification is defined as a learning technique that focuses on game mechanics that can be applied in the educational-professional environment (Grabner-Hagen & Kingsley, 2023; McHenry & Makarius, 2023; Murillo-Zamorano et al., 2023; Ogunyemi et al., 2022; Orhan Göksün & Gürsoy, 2019; Sanchez et al., 2020; Schöbel et al., 2021). The theoretical foundation of gamification is based on the motivation towards individuals as this can be regulated by external factors, this is because a behavior is influenced by recognition, accumulation of goods or the allocation of rewards. Motivation allows the analysis of behavioral variables in response to specific stimuli (Menon, 2022).

Gamification can be represented as a pyramid scheme like Werbach model. As shown in Figure 1, at the base of both schemes, medals, avatars, points, and levels are proposed as elements. In the second level, the mechanical elements are detailed, where challenges, cooperation and rewards are established. The last level describes the processing of mechanical elements such as dynamics that promote emotional stimulation (Gaviria, 2021).

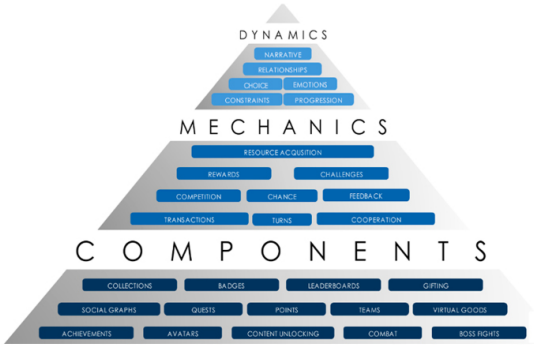

Figure 1. Werbach scheme obtained from (Gaviria, 2021).

Grammatically, gamification is referred to as ludification, since according to the RAE, the term “gamification” is considered an anglicism and neologism. However, gamification is based on the elements of a motivational system while gamification focuses on the contents of the system. In the educational context, gamification is a frequently used tool due to the massification of computing devices and the development of interactive and graphic situations for entertainment using information and communication technologies (Pynnönen et al., 2022).

As detailed in this context, playfulness is the basis of gamification in an educational process, however, gamification must be justified why it is required to incorporate certain disaggregated activities. Currently, the state of the art in reference to the application of gamification techniques in the ludic-educational field is extensive at different levels of education. However, there is little information regarding the use of gamification at the preschool level (Zainuddin et al., 2020).

According to (Marcillo et al., 2023) there is a significant increase in the number of research on gamification considering from 2014 to 2019. Also, these researches on these techniques are mostly in Asian countries than in American and European countries, mainly seeking to improve student learning, social skills and motivation in individuals based on technological tools. In Ecuador, education still presents methodologies that do not relate communication and entertainment. Gamification is an alternative that can allow to establish new discoveries, new ideas, learning that are designed by meaningful experiences for personal and intellectual development.

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The objective of this study was to evaluate logical-mathematical skills through a mobile application designed by gamification techniques. Furthermore, the present study is subdivided into materials and methods where the experimental design is detailed, followed by the results and conclusions, and finally annexes that support the study methodology.

2. Methology

2.1. Population and sample size

Within this study, two heterogeneous groups (study groups) were determined, which are part of the preschool education level, coastal regime of Ecuador in the province of Santo Domingo. The groups were divided by age, the first group being students from 3 to 4 years old (n = 158) corresponding to the first level of preschool education and the second group, students from 4 to 5 years old corresponding to the second level of preschool education (n = 143).

2.2. Gamification

The gamification process was developed using the mobile application PREESCOLAR MONTESSORI ® copyrighted by EDOKI ACADEMY designed in the year 2021, the mobile application in question was used for educational purposes, not commercial. The mobile application was designed by certified teachers in the Montessori method, this application is focused on students from 3 to 7 years old who can acquire knowledge related to logical-mathematical skills, art, practical life, and early literacy.

2.3. Standardization of logical-mathematical skills assessment

For the evaluation of the improvement of logical-mathematical skills, the parameters for the evaluation of learning objectives established by the Ministry of Education of Ecuador in the year 2021 were taken into consideration. The parameters to be considered are detailed in Annex A, where the topics that contemplate logical-mathematical skills in preschool students are detailed (MINEDUC, 2014).

2.4. Statistical analysis

A completely randomized bifactorial design (A x B) was proposed considering the following factors: Factor A: Study groups and Factor B: Learning objectives. For this study, 2 replicates (number of attempts) were considered; the total number of experimental units was 28. Table 1 shows the table of treatments to be evaluated in the study.

Table 1. Treatment scheme for the bifactor analysis.
Source: Authors.

Factors of study	Levels
Factor A: Study groups	A0: Group A (Students from 3 to 4 years old) A1: Group B (Students from 4 to 5 years old)
Factor B: Learning objectives	B0: Objective 1 B1: Objective 2 B2: Objective 3 B3: Objective 4 B4: Objective 5 B5: Objective 6 B6: Objective 7

In this study, the average evaluation obtained from each student was determined as the dependent variable. For the grading scale, a quantitative range of 5,00 to 10,00 was established, considering the grading scale for preschool education approved by the Ministry of Education of Ecuador in 2014, in Table 2, the mentioned grading scale is detailed. For the statistical analysis, an analysis of variance was performed and for significance tests, the LSD Fisher test was applied considering a confidence level of 95 %.

Table 2. Grading scale in Initial Education established by MINEDUC.
Source: (MINEDUC, 2014).

Scale	Meaning	Process characteristics
5,00 to 6,99	Start	The student is initiating the development of skills that will enable him/her to achieve the learning or evidences difficulties.
7,00 to 8,99	In process	The student is in the process of achieving prior learning.
9,00 to 10,00	Available	The student achieves the acquired learning.

3. Results

3.1. Analysis of variance

According to the results obtained, a significant difference was observed in the evaluation averages of the study groups; however, no significant difference was observed in the learning objectives evaluated, nor was a significant difference observed in the bifactor interaction and the replications of the study, as shown in Table 3.

Table 3. Analysis of variance of the average evaluation obtained.
Source: Authors.

Source of variation	Sum of squares	Df	Mean squares	F-Ratio	p-value
Study groups	11,843	1	11,843	6,25	0,0266
Learning objectives	8,91944	6	1,48657	0,78	0,5972
Number of attempts	0,04088	1	0,04088	0,02	0,8855
Study groups * Learning objectives	7,97587	6	1,32931	0,70	0,6539
Residuals	24,6369	13	1,89514		
Total	53,4161	27			

3.2. Significance test

For factor A, independent groups were observed, in which group

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1 obtained a higher average evaluation score compared to group 2, as shown in Figure 2.

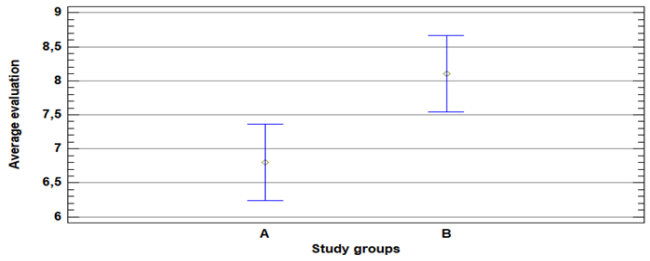

Figure 2. Box plot for factor A: Study groups A and B.

For factor B, an independent group was observed, that is, the evaluation averages obtained for each learning objective evaluated are statistically similar; however, the learning objective where the highest average score was determined was learning objective 1, as shown in Figure 3

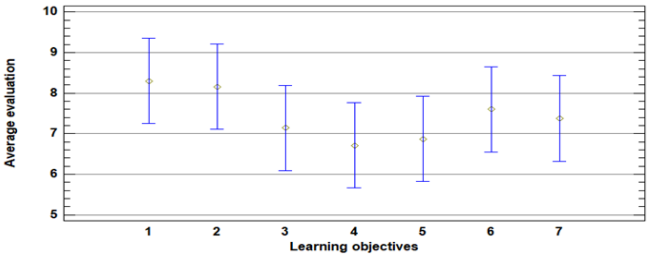

Figure 3. Box plot for factor A: Study groups A and B.

For the bifactor interaction, 3 homologous groups were obtained as a result, according to the LSD Fisher test, the interaction of group 1 evaluating objective 2 presents a higher average compared to the other bifactor interactions, as shown in Figure 4.

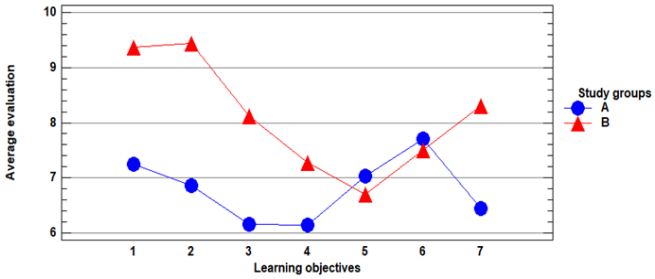

Figure 4. Bifactor interaction plot, study groups by learning objectives assessed.

3.3. Analysis of results

According to the study groups, it was observed that they present a significant difference in the average evaluation obtained, that is, group A is at the beginning of acquiring skills that allow it to acquire the required learning, while group B is in the process of acquiring the required learning, these results are supported by several factors, one of them is the lack of use of gamification techniques for the purpose of gamification of learning in preschool students.

According to (Marcillo et al., 2023) in its literature review on the state of the art of gamification in educational processes, it states that of a sample size (studies analyzed, n = 1553) in Ecuador no experimental studies have been reported on the use of gamification for the improvement of logical-mathematical skills, unlike Colombia, Mexico, Spain and Brazil, this corroborates the results obtained, since being a new gamification technique in a learning development already established as in Ecuador, it can influence the academic performance of students (MINEDUC, 2022).

At the preschool level, there are various teaching-learning methods, in Ecuador, through the "National Plan Learning on Time" developed by the Ministry of Education of Ecuador in 2021, states that learning is based on love, security, trust and quality attention, it also states that gamification improves their coordination, assimilation of notions of time and space for a better interneural network (MINEDUC, 2022).

On the other hand, according to the learning objectives evaluated, no significant difference was obtained in the averages obtained; however, in objectives 4 and 5, the students are in a beginning stage of acquiring skills to acquire knowledge, while in the other objectives, the students are in the process of acquiring the required knowledge (Arufe-Giráldez et al., 2022; Chen et al., 2020; Sanchez et al., 2020; Zainuddin et al., 2020).

According to (Blundell et al., 2022; Grabner-Hagen & Kingsley, 2023; MINEDUC, 2022; Ogunyemi et al., 2022) it is worth noting that of the articles published on gamification, only 20% are experimental research and 80% are narrative, non-experimental, explanatory, or exploratory, which indicates that it is an open field for research and improvement of teaching-learning methodologies. According to the World Bank, 62.8 % of basic general students have not reached the minimum reading skill, in the PISA-D evaluation. In 2019, Ecuador reported that 54 % of students do not have the minimum knowledge in reading

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and 71 % in mathematical knowledge (Arufe-Giráldez et al., 2022; Chen et al., 2020; Marcillo et al., 2023; Zainuddin et al., 2020).

This corroborates the results obtained in the interaction study groups and learning objectives evaluated since group A in objective 3, 4 and 7, obtained a score of beginning learning, however, in objectives 1, 2 and 5 they obtained a score in process. On the other hand, the group of students B, in objective 5, obtained an initial qualification while in objectives 3, 4, 6 and 7, they obtained a qualification in process and in objectives 1 and 2 they reached the acquired knowledge. These results demonstrate the lack of innovation in the current educational development methods in Ecuador, for which gamification is an alternative.

4. Conclusions

It is concluded that student group A is at the beginning of acquiring knowledge skills, while group B is in the process of acquiring knowledge skills regarding mathematical logic. As for the learning assessment objectives, in objectives 4 and 5 the students are in the beginning of acquiring knowledge skills in mathematical logic, while in the rest of the objectives assessed, the students are in the process of acquiring knowledge skills. In the study replications (number of evaluation attempts), no significant difference was observed; therefore, there is normality in the data collection.

Gamification is a tool that allows improving teaching-learning techniques at any level of studies, however, it should be evaluated with greater emphasis for the purpose of gamification of knowledge at preschool level due to the low results in knowledge tests of students in Ecuador according to bibliographic references.

Mobile applications play an important role since they are the gamification mechanism through which the student interacts; therefore, curricular designs for education should be based on gamification of the challenge type so that the student is motivated to obtain a result. ICT are also of great help for the gamification of knowledge, considering the new learning methods of the new generations and the massification of information.

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Contribution of authors

Fabricio Marcillo Vera: supervision, writing - drafting and editing of the article. **Lorena Cusme Velez:** software and formal analysis. **Jimmy Torres Bastidas:** visualization and research. **Jessica Dueñas Hidalgo:** conceptualization and methodology.

Conflictos de interés

Los autores declaran no tener ningún conflicto de interés.

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Appendix

Appendix A. Learning objectives evaluated, modified from (MINEDUC, 2014).

Learning Objectives	Skills from 3 to 4 years old	Skills from 4 to 5 years old
Objective 1. Identify basic temporal notions for their location in time and the structuring of logical sequences that facilitate the development of thought.	Order a logical sequence of up to three events.	Order in logical sequence of events up to five events.
	Identify characteristics of day and night.	Identify characteristics of morning, afternoon, and evening.
	Identify notions of time in actions that happen before and now.	Identify notions of time in actions that happen before, now, and after.
Objective 2. Manage basic spatial notions for the proper location of objects and their interaction with them.	Recognize the location of objects in relation to self-according to spatial notions of up/down, next to, inside/outside, near/far.	Recognize the location of objects in relation to self and different points of reference, according to the spatial notions of between, front/back, next to, near/far.
Objective 3. Identify the basic notions of measurement in objects establishing comparisons between them.	Identify in objects, the notions of average: high/low, fish/light.	Identify in objects the notions of measurement: long/short, thick/thin.
Objective 4. Discriminate shapes and colors developing their perceptual ability to understand their environment.	Identify objects of similar shapes in the environment.	Associate the shapes of environmental objects with two-dimensional geometric figures.
	Discover basic circular, triangular, rectangular, and quadrangular shapes in environmental objects.	Identify basic geometric shapes such as circles, squares and triangles in environmental objects and graphic representations.
	Recognize primary colors, black and white in objects and images in the environment.	Recognize secondary colors in environmental objects and images.
Objective 5. To understand basic notions of quantity facilitating the development of thinking skills for the solution of simple problems.	Count orally from 1 to 10 in numerical sequence, most of the time.	Count orally from 1 to 15 in numerical sequence.
	Differentiate between collections of more and fewer objects.	Compare and assemble collections of more, equal, and fewer objects.
	Understand the number-quantity relationship up to 5.	Understand the number-quantity relationship up to 10.
	Recognize and compare objects according to their size (big/small).	Sequentially compare and sort a small set of objects according to size.
	Classify objects with an attribute (size, shape, or color).	Sort objects with two attributes (size, color, shape).
	Imitate simple patterns with elements of their environment.	Continue and reproduce simple patterns with concrete objects and graphic representations.
Objective 6. To aurally discriminate the phonemes (sounds) that make up their native language to lay the foundations for the future reading process.	Repeat rhymes by identifying sounds that sound alike.	Produce words that rhyme spontaneously considering the final sounds of the words.
	Identify "aurally" the initial phoneme (sound) of their name.	Identify "aurally" the initial phoneme (sound) of the most frequently used words.

Learning Objectives	Skills from 3 to 4 years old	Skills from 4 to 5 years old
Objective 7. To use graphic language as a means of communication and written expression to lay the foundations for the processes of writing and producing texts in a creative way.	Communicate through drawings of objects in the environment with some detail that makes it identifiable as a symbolic representation of their ideas.	Communicate through drawings of objects with details that make them identifiable, as a symbolic representation of their ideas.
	Communicate in written form their ideas through controlled scribbles, lines, or circles.	Communicate ideas in writing by trying to imitate letters or letter-like shapes.

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