The Impact of Gamified Education on Children and Adolescents in STEAM Education as a future Teaching Methodology in Remote Areas of the Arequipa Region – Peru

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Abstract

The main objective of this study is to analyze how teachers adopt gamified practices for didactic purposes to achieve positive behaviors in the active motivation of students. The study was carried out in tambos in the Arequipa and Huancayo regions, and a questionnaire was administered to students to validate the information. The study also observed the degree of interest or rejection that the methodology generates. The methodology used was non-experimental and had two well-defined phases. First, an exploratory factor analysis was performed, which aimed to condense the information in original variables into smaller series. Second, a confirmatory factor analysis was performed using structural equation modeling. The results of the study show that the viability of dynamic resources of competition and challenges has a positive influence on the inclusion of students in gamification. The partial least squares structural equation model was calculated for these data based on an exploratory-confirmatory model and using SmartPLS version 4.0.

Keywords
Gamification, STEAM, Fabrication Laboratory, didactic, SMART PLS, SEM.

1. Introduction

Why is important to gamificate?

Gamification and sustainability are two key concepts in higher and elementary education, and have gained relevance in recent years due to their potential to promote educational inclusion. This relevance is mainly due to the interest that students have in standing out or being noticed for their abilities [1].Gamification is the use of game-like elements and mechanics in non-game contexts. It can be used to make learning more engaging and fun, and to promote motivation and engagement.

It is worth noting that this practice has always been in force in the classroom, however, it has not been taken to a type of practical methodology as an academic policy. Competition always works as an element of fun, it is also useful to use progression methods, so that the student can climb or have the notion that they are gradually going up a "level", as they progress, they generate rewards that improve attention and permanent interest in the academic day.

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It is important to note that gamification refers to the use of game elements and dynamics in non-game contexts, such as education, in order to motivate, engage and improve student learning [2]. On the other hand, sustainability focuses on the development of practices and models that promote balance between social, economic, and environmental aspects, thus ensuring a sustainable future for future generations.

There are a variety of research studies in Peru on the use of gamification in reading comprehension among students during and after the pandemic. One of the main points is that it is easier to generate playful activities in the field of communication, as proposed by Calderón Arévalo et al., n.d. It is important to note that these research studies do not only consider analog methods, but also digital methods such as video games. This is well-illustrated by a study conducted by the "Pontificia Universidad Católica del Perú", which looked at the field of mathematics and found that mastery of mathematics is not only achieved through problems, but also through digital video game activities that develop their calculation skills [4].

The research highlights its importance in the initiative of a methodology for children from remote areas, where education is scarce and outdated. It also aims to analyze the degree of acceptance that children (students) have in adopting this gamified methodology in technology [5]

This research contributes directly to studies in the field of gamification in children, where the "what" and "how" of our practices in real environments and with real-time results are analyzed[6], in addition to teamwork and progress in remote areas with the most powerful weapon, education and learning resources. Additionally, we explore the field of psychological perspective and the continuous improvement of playful formats with technology, collect different information from regional, national and international sources in favor of a grounded and powerful methodology with the help of robotics and future projects with a positive outlook on cultural activities in each region (TAMBO). It is important to highlight the joint work between education, government and society as responsible entities for bridging the gaps of inequality in Peru, in this case Arequipa and Huancayo.

As proposed by Gil-Aciron, the theoretical basis of gamified education includes fields such as psychology, technology, pedagogy, and even philosophy. Highlighting psychology in this field, it is important to mention that the personalization of playful activities effectively improves the design of a game. The experience depends on the context in which learning takes place and this is highly related to the psychological characteristics of students as detailed in the journals of interactive learning environments.

From a technological perspective, local research has been carried out, such as that developed at the UPC, where the academic performance of first-cycle students in mathematics was evaluated. The correlation between the playful methodology and its positive impact on performance was evaluated. Post-class research shows that gamification can have positive results in both young people over 18 and children under 13 [8]

It is important to note that the references in this theoretical framework date from recent years, highlighting that due to ICTs (information and communication technologies) and the pandemic process, many more digital practices have been adopted that are mutating into a kind of "digital game in teaching". This is because it is important to highlight that the rates of disinterest in attending virtual classes in young people is higher than in face-to-face classes. This has led teachers in primary, secondary and higher education to adopt not only digitization but also gamification in order to capture more student attention and also more interactivity [9]

It is worth mentioning that the Ministry of Education (MINEDU) has magazines and research that evaluate gamification in education and the current state of the matter [10].

In this perspective, together with the pyramid of gamification elements, the economic aspects that would be generated by adopting this methodology were evaluated. The results showed a significant effort, as the problem of going against the overstimulation of students was also taken into account. Knowing that 7 out of 10 students have access to video games, and fearing that this could lead to gambling addiction or antisocial behavior, it is very important to consider contextual aspects. In this research, the centers where gamification is to be applied are the TAMBOS of the PAIS program, where the first advances with robotics for children in these remote areas have been visited and generated.

Based on the above considerations, the following hypotheses are proposed:

H1. There is a positive the impact of the playful application in gamification

H2. There is a positive the impact of the initial motivation application in gamification

H3. There is a positive the impact of the playful sustainability in gamification

H4. There is a positive the impact of the playful viability in gamification

2. Methodology

The research employed a non-experimental approach and consisted of two distinct stages. In the initial phase, exploratory factor analysis was conducted to consolidate the information from the original variables into smaller sets. Subsequently, confirmatory factor analysis was undertaken using structural equation modeling.

The application of the instrument was carried out in the month of May and June 2023. In order to assess the reliability of the instrument, a pilot study was conducted with a sample of 50 students. The instrument was found to be reliable, with Cronbach's alpha of 0.765 and McDonald's omega of 0.864. In addition, the Kaiser-Meyer-Olkin (KMO) test indicated that the items fit well within their respective factors, with a KMO value of 0.841 and a significance level of 0.000. The statistical calculations were performed using the IBM SPSS Statistics (v. 27), Smart PLS (v. 4.0), and JASP (v.0.17) software packages.

Table 1 presents the reliability indices for the observed variables, which are acceptable for both cases, using Cronbach's alpha (α) and McDonald's (ω).

Table 1
Reliability indices

Variables	Cronbach's alpha α	McDonald's ω
S	0.844	0.74
M	0.862	0.86
V	0.798	0.72
A	0.784	0.81

The instrument employs a 5-point scale, a Likert scale [11], with 1 indicating complete disagreement and 7 indicating complete agreement. Data collection was carried out through an online survey. The sample for the study consisted of 150 education students from Universidad Continental, the students were randomly selected being 47.0% men and 63.0 women, whose ages are between 16 and 24 years. Check Table 2.

Table 2
Sample studied

Amount	Male	Female
N	60	90

3. Results

The statistical procedure that was carried out to determine the degree of reliability of the research instrument for data collection was Cronbach's Alpha, being the results obtained

α = 0,765 which meaning is interpreted as good [12].

Next, we carried out the exploratory factor analysis (EFA) tests where the grouping of the items in their respective variables was analyzed, giving us ideal certainty of our data, the Kaiser-Meyer-Olkin (KMO) test and the Bartlett sphericity test were used [13], [14].

The KMO result was 0.841, which meaning is interpreted as good.

In the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA), the following nomenclature was used: Dependent variable of model 1= NPS Gamification; and de independent variables: 2= expected sustainability (S); 3= initial motivation (M); 4= expected feasibility (V); 5= playful application (A).
Table 3 presents the results of the sample adequacy, outer loadings.

Table 3
Outer loadings – Smart PLS

Items			**Factors**		
	NSP	Feasibility	Sustainability	Motivation	Application
A1					0.791
A6					0.791
A8					0.782
A9					0.796
M1				0.848	
M3				0.806	
M5				0.812	
NPS	1.000				
S1			0.727		
S3			0.970		
V2		0.741			
V4		0.742			
V5		0.778			

To determine the robustness of the model, confirmatory factor analysis (CFA) was used, using the CB-SEM analysis of covariance method, it was used Smart PLS.4.

For the reliability analysis of the construct or internal consistency, this was performed through Cronbach's Alpha ≥ 0.7, Composite Reliability (ρc) ≥ 0.7 suggested by [15] The results obtained exceed the minimum fit indices required. In terms of the Convergent Validity criterion, the Average Variance Extracted (AVE) was used, the values must be ≥ 0.5, this indicates that the construct explains at least 50% of the variance of its elements, as shown in table 4; the results are quite satisfactory, as all of the values exceed 0.500. As for using the (rho_A) coefficient as a construct reliability criterion, it is recommended to verify the reliability of the values obtained in the construction and design of PLS-SEM. The results obtained in (rho_A) must have values of 0.7 or higher to demonstrate composite reliability. The results obtained are between 0.7 and 0.9.

Table 4
Assessment of the measurement model for reflective constructs.

	Cronbach's alpha	**rho_A**	**Composi-te reliability**	**(AVE)**
Expected feasibility	0.721	0.720	0.798	0.569
Expected sustainability	0.700	1.283	0.844	0.735
Initial motivation	0.765	0.784	0.862	0.676
Playful application	0.734	0.733	0.784	0.676

The discriminant validity test of the model, which will allow us to know to what extent the construct is different from other constructs or measures different things. In table 5, using the Fornell-Larcker criterion, there is discriminant validity [16] in the latent variables that are part of the structural model.

Table 5
Assessment of the measurement model for reflective constructs.

	NPS Gamification	Expected feasibility	Expected sustainability	Initial motivation	Playful application
NPS Gamification	1.000				
Expected feasibility	0.507	0.754			
Expected sustainability	0.522	0.567	0.857		
Initial motivation	0.631	0.551	0.563	0.822	
Playful application	0.628	0.633	0.569	0.608	0.790

Another criterion to know the Discriminant Validity in reflexive models is the so-called Heterotrait-Monotrait (HTMT) [17], [18] It is defined as the mean of the element correlations between the constructs relative to the mean (geometric) of the average correlations for the elements that measure the same construct. The acceptance threshold should be in the following proportions ≤ 0.85 ≤ 0.9. According to the results obtained, it also meets the discriminant validity criterion. See Table 6.

Table 6
Assessment of the measurement model for reflective constructs.

	NPS Gamification	Expected feasibility	Expected sustainability	Initial motivation	Playful application
NPS Gamification					
Expected feasibility	0.514				
Expected sustainability	0.223	0.395			
Initial motivation	0.478	0.650	0.299		
Playful application	0.783	0.840	0.243	0.721	

In figure 1, is a graphical representation of the composite reliability and validity analysis of the model, based on the R2 (determination coefficient). the results obtained through the results of R2 show statistically significant effects of influence between one and the other variables of the model.

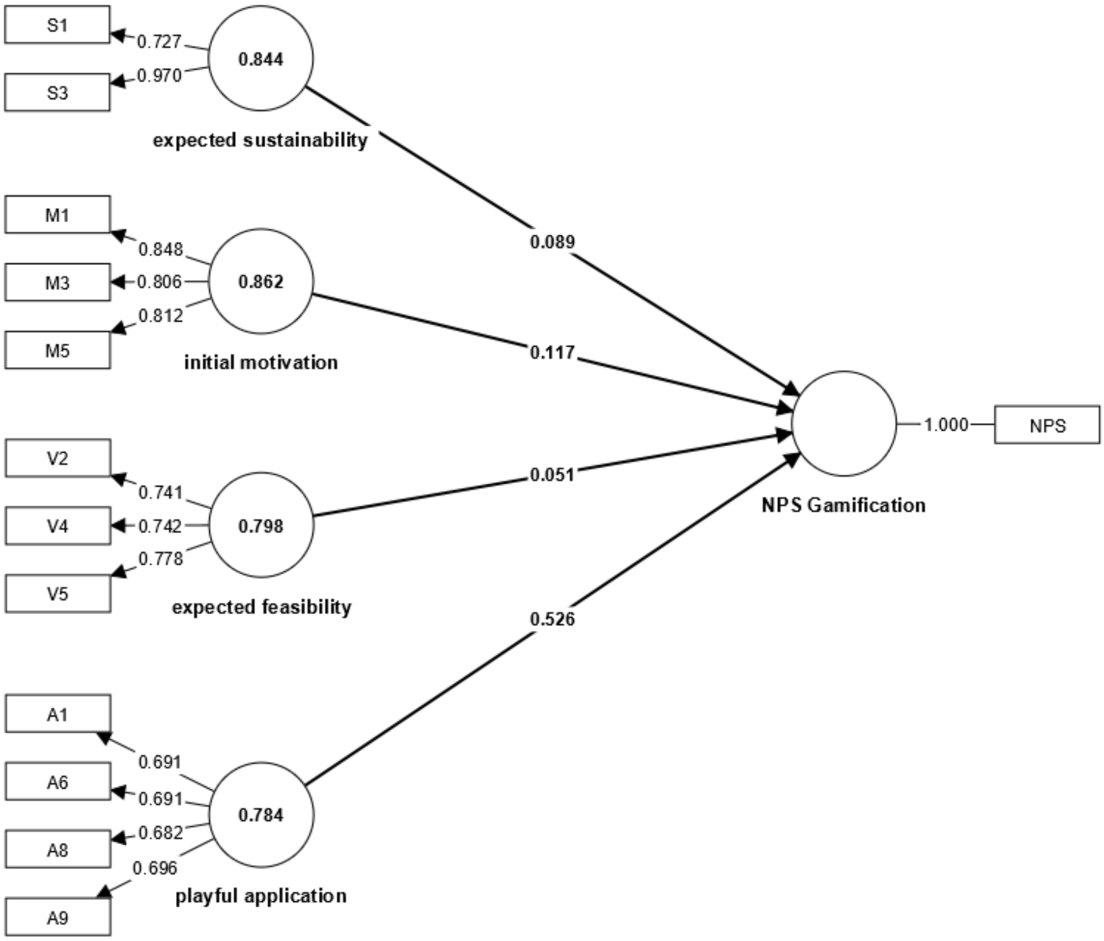

Figure 1: Composite reliability and validity analysis

The results, explained from the R2 (coefficient of determination) to establish the relationship between the proposed factors in the model, are obtained in the dependent variable, that is, the factorial loads that the independent variables exert are translated into the R2(coefficient of determination) with an effect of 0.421 using Partial Least Squares Structural Equation Modeling (PLS-SEM), which is equivalent to say 42.1% that explains the model and that 57.9% is explained by other variables that are not part of the proposed model. See figure 2.

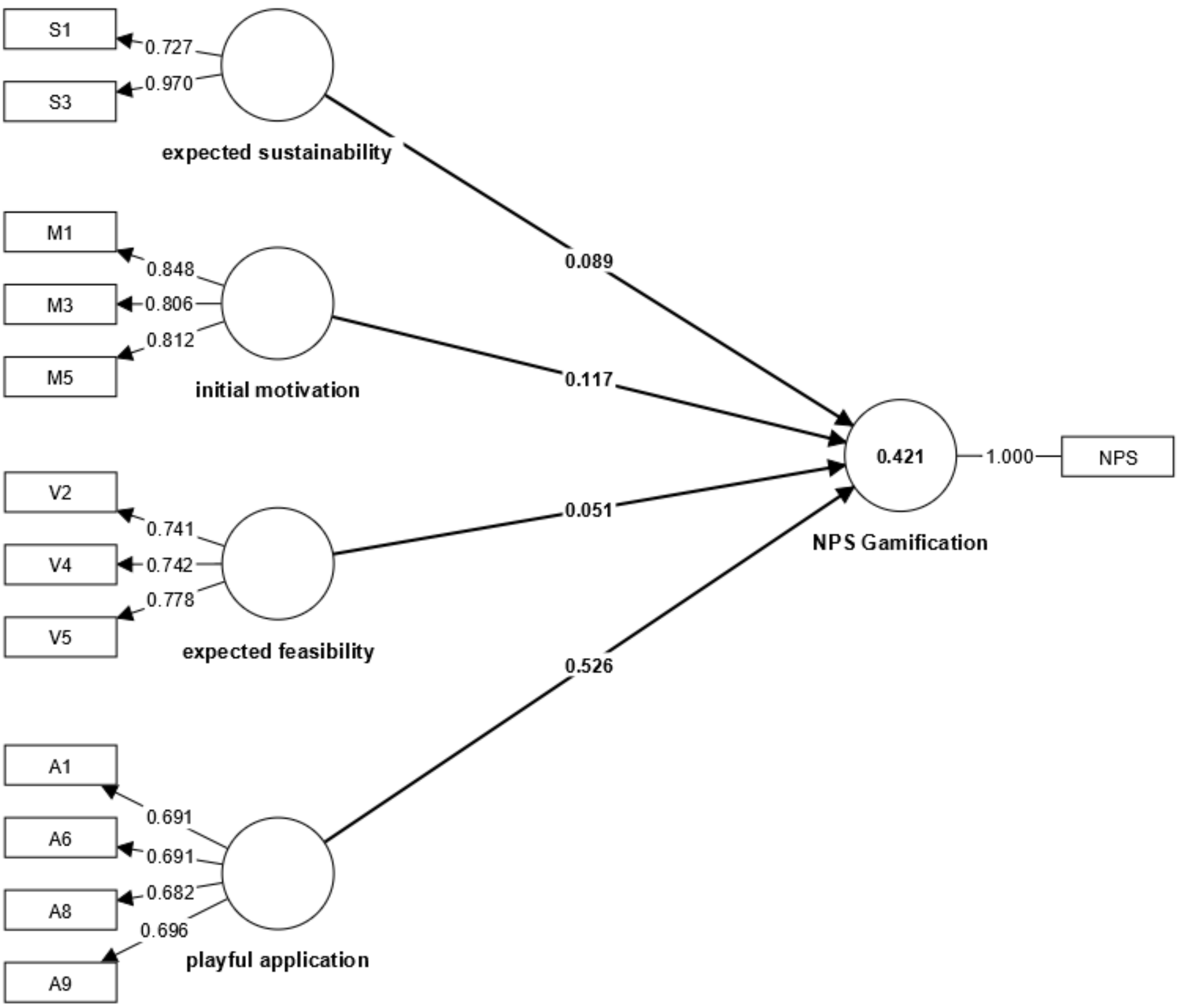

Figure 2: R2 - path coefficients and p values – SmartPLS

This study is focused especially on the level of influence of the different factors as independent variables that could influence the Gamify recommendation, The goodness of the structural model has allowed us to generate other statistically reasonable relationships of influence and causality. Table 7 shows the Bootstrapping results, and how the variables in the model were hypothesized. Therefore, considering the P-Value ($p < 0.05$), the hypotheses H4 are accepted and the hypotheses H1, H2, H3 are rejected.

The bootstrapping method allows us to know that the relationships are significantly different from zero. This is done by extracting a large number of bootstrap samples (10,000) with replacement from the original sample and then estimating the model parameters for each bootstrap sample. The standard error of an estimate is inferred from the standard deviation of the bootstrap estimates; therefore one hypothesis is accepted.

Table 7
Bootstrapping test results.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T statistics (|O/STDEV |)	P Value
Expected feasibility -> NPS Gamification	0.051	0.067	0.092	0.552	0.581

Expected sustainability -> NPS Gamification	0.089	0.085	0.110	0.806	0.420
initial motivation -> NPS Gamification	0.117	0.129	0.094	1.248	0.212
Playful application -> NPS Gamification	0.526	0.516	0.098	5.370	0.000

4. Conclusions

The data analysis reveals several important findings: The interest in a gamified (NPS) class is not positively affected by efforts to make game-playing more viable (V) in class. In other words, children in rural areas prefer to play from the beginning while learning, rather than attending to instructions that constantly validate their attention. This underlines the importance of fostering more direct and responsive teaching attitudes towards children on dairy farms.

The interest in a gamified class (NPS) is not positively affected by the constant expectation (S) in class, which validates the first rejected hypothesis. The behavior of these rural centers is more dynamic and does not require breaks

The interest in a gamified (NPS) class is not positively affected by the primary motivation (M), which suggests that better results are obtained by playing with curiosity rather than presenting the entire initial work plan to "motivate" children.

The initial game in a gamified (A) class has a positive impact on student interest. Starting with the game and communicating that it is part of the lesson, along with showing the pieces and robots, helps students stay engaged in the playful learning experience, which has a final deliverable as a goal. The class should be uninterrupted to maintain student interest.

In summary, this research highlights the importance of teacher attitudes and skills, as well as the perceived usefulness and ease of teaching when using the proposed gamified models. These findings underscore the importance of teachers adopting gamified attitudes to teach complex subjects that become simpler when made playful. See figure 3.

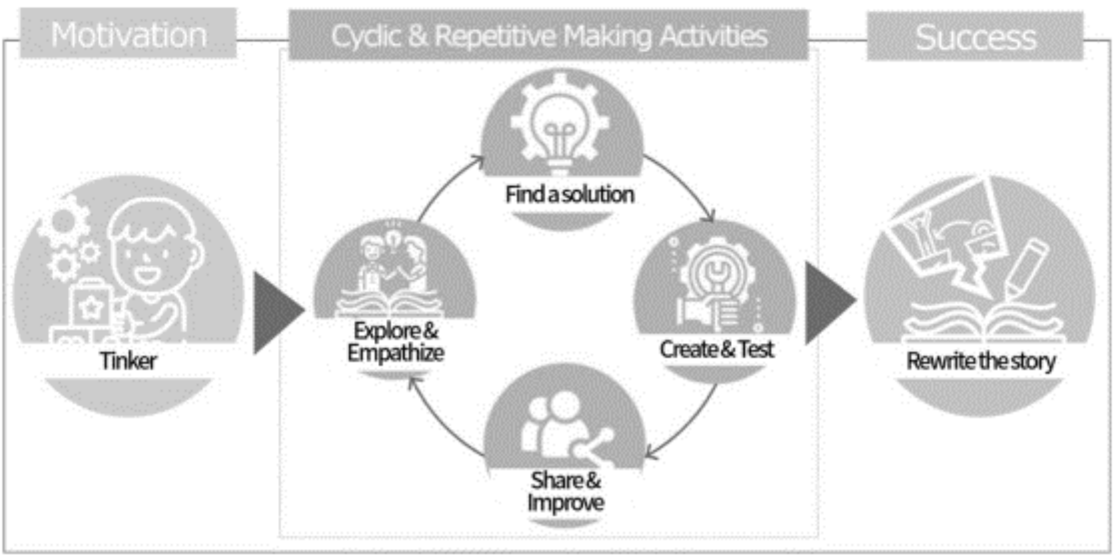

Figure 3: Revised NE-Maker Instructional Model [19]

5. Acknowledgements

Research participants and dairy managers are thanked for helping to teach their remote areas of the country with STEAM. In figure 4, Using the previously explained methodology using gamification, we obtained: More than 210 robots designed and built by students themselves, 90% interest in robotics and part manufacturing, 80% learned to use Thinkercad collaboratively for assembly, more than 90 hours in design, assembly, and STEM teaching in remote areas of Peru.

Figure 4: Assembly and programming of STEAM robots (Gamified)

6. Discussions

Creativity is an essential human ability for personal and professional development. It is defined as the ability to generate new, original, and useful ideas. It is a skill that can be learned and developed, and it is essential for problem-solving, innovation, and adaptation to change.

In the context of early childhood education, creativity is a fundamental ability that should be fostered. Children are naturally curious and imaginative, and they have a great capacity for generating new ideas. It is important for educators to provide children with opportunities to explore their creativity through activities that allow them to experiment, try new things, and think outside the box. One way to foster creativity in children is through the teaching of robotics. Robotics is a discipline that combines science, technology, engineering, and mathematics. It is a discipline that offers children opportunities to develop their creativity in a playful and stimulating context [20]

Robotics allows children to give free rein to their imagination and create original projects. Children must design, build, and program robots to perform specific tasks. This process requires a high level of creativity, as children must think of innovative solutions to the problems they are presented with. Check table 8 for the evaluation of creativity in robotics projects is a complex task. It is important to consider a variety of factors, such as the originality of ideas, the feasibility of the project, the quality of execution, and the impact of the project. [21]

Table 8
Creativity rubric for STEAM class experts to rate student projects

	Dimension of gaming creativity class	SA	A	D	SD	NA	Comments
1	Clarity of objectives						
2	Engagement of students						
3	Use of game elements						
4	Relevance of content						
5	Assessment of learning						
6	Overall effectiveness						
7	Use of technology						
8	Variety of activities						
9	Positive reinforcement						

SA=strongly agree; A=agree; D=disagree; SD=strongly disagree; NA=not applicable

7. Limitations

Some of the limitations in this study is an inadequate facilities and equipment: Remote schools may have outdated or insufficient facilities and equipment for conducting hands-on STEAM experiments and activities, restricting students' exposure to practical applications of STEM concepts, also the remote areas are often geographically isolated, making it difficult for students to participate in collaborative STEAM projects, competitions, and events that can enhance their learning experience.

In addition, data collection by children will be a challenge considering their reading comprehension skills. This is why it would be necessary to have child psychologists specialized in the analysis of their behavior to evaluate the gamified impact in more depth.

Our study intends to continue practicing gamification in rural areas of the country, in order to evaluate and collect more information to make a larger system of playful steps useful for learning robotics in remote areas of Peru.

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