Usability Analysis and Clustering Model in e-Learning from the User Experience Perspective

Fabiola Talavera-Mendoza, Carlos E. Atencio-Torres, Henry del Carpio, David A. Deza, and Alexander R. Cayro

***Abstract*—Online learning offers opportunities responding to their different individual and group learning needs by leaving digital traces that allow tracking their experiences at the user level. This study aims to examine the perceived usability of the gamified educational platform called (ELORS) in relation to online behaviour. As well as analyse the clustering models in terms of their high and low level of engagement through their interaction metrics. A quantitative, descriptive correlational approach and an educational data analysis design was adopted through the K-means algorithm. The participants were 51 students in mathematics in the second year of secondary education. An instrument was used to evaluate usability and behavioural metrics, analysing 1065 interactions with 57 activities. The results showed advantages in usability and grouping. The level of usability achieved depends on the interaction of the users with the different learning objects and their moderate relationship in their interactions. In relation to the centroids, two groups are evidenced by number of attempts and interactions, identifying students with low levels of participation in the minority. A significant finding is given in relation to the preference of redeeming virtual values in gold from the diamonds collected. The perspective of the analysis allows identifying the potential of the gamified platform to work online in the formation of mathematical competence according to the current educational curriculum.**

***Index Terms*—Usability, gamified educational platform, online learning, K-means clustering.**

I. Introduction

Online education is an indispensable element that provides data that can be observable, modifiable, and adaptable in real time, depending on the level of the student's behaviour in educational platforms [1], finding logical relationships using data mining, which can lead to personalization of learning [2], [3].

Among the advantages of online learning are: a) ease of use, familiarity with their interaction and frequency of the device thus mitigating the cognitive load and effective fulfilment of tasks, b) The contents, not only receive training sessions, but can access other complementary training materials and c) communication capabilities through a specific network, such as chat messages, SMS, voice calls, shared calendars, access to forums, etc., which promotes cooperation in the learning process [4].

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In the literature found, it points out that this online learning can be accompanied by gamification that the effects of points, ranking and badges allows greater participation, learning and a level of behaviour that favours in personality traits [5], as well as engagement and motivation through incorporation of game elements [6], [7] in order to stimulate and significantly develop in students their curricular, cognitive and social competencies [8], with habit reinforcement and rewards [9], [10], all based on games that lead to problem solving, creative thinking and strategic decision making through fun and motivation in the development of learning [11].

Similarly, a user-based assessment experience demonstrates that more motivated students strived for better rewards and grades, while students less interested in the tasks did not exceed their score limits in the leader boards [12]. Therefore, it is essential to be able to correctly classify students in their different levels of engagement, to identify those who are not engaged and need help [1]. Therefore, in this work we aim to identify the level of student engagement on the platform in problem solving using unsupervised learning algorithms to group students, according to their frequencies of online interaction, to describe their student engagement in completing the tasks.

Thus, usability also plays a fundamental role in the acceptance and effectiveness of e-learning platforms [13], which allow identifying the strengths and weaknesses associated with the site design [14]. Perceived usability being the reflection of subjective user evaluations [15]. ISO 9241-11 prescribes the following usability measures: a) Effectiveness, related to users' ability to complete tasks using the system and the quality of the outcome of those tasks, b) Efficiency, the uses, and interactions for task completion, and c) Satisfaction, users' personal reactions to using the system [16]. There are theoretical approaches on proposals to evaluate the usability of gamified platforms [17], [18], [19] based on a model of student interaction with the content in a playful way, as well as the evaluation of the preferences of the usability variables in the e-learning system based on the students' perspectives [20], as well as Nielsen's model to evaluate learning, efficiency, memorability, error, satisfaction and navigation; which proved to be effective and efficient [21].

In general, the literature discussed highlights the importance of analysing the relevance of gamification and student engagement but focused on motivation and usability in higher education rather than in basic education contexts [12]. Therefore, the potential of platforms with gamified approaches for secondary schools are scarcely analysed, which implies that it is necessary to conduct more research in the area and identify the usability criteria in user interfaces in online learning platforms and to use the K-means algorithm,

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to directly link the database of the learning platform and receive updated and automated information [22], generating groupings that allow finding a common characteristic [1]. As we can analyse there are many researchers who have made efforts to include gamification elements in learning platforms, to our knowledge, there are few works on the evaluation of usability in the gamified learning platform [17], [20] and how the bridge can be created for the e-learning personalization process, so the groupings help the system to make better recommendations.

The contribution of our work lies in the analysis of the metrics in its elements of gamification and behaviour in a gamified educational platform ELORS in the educational context of secondary education. The general objective is to correlate the degree of usability of the different learning objects with the gold obtained, experience and achievement obtained through the gamified educational platform ELORS, from the users' perspective. As well as the specific objectives: To analyse the degree of perceived usability in the interaction of the different learning objects and its significance with the level obtained by the students. To understand how participation level patterns occur in terms of time, number of attempts, activity status, number of interactions and level of achievement in the ELORS gamified platform, using online learning.

A. *ELORS Gamified Educational Platform*

The ELOS educational platform has been created for the teaching of mathematics and allows users to have a dynamic and intuitive interaction, facilitating the learning and development of mathematical skills, for this it has been divided into different sections to facilitate student navigation and development of the different activities and challenges proposed.

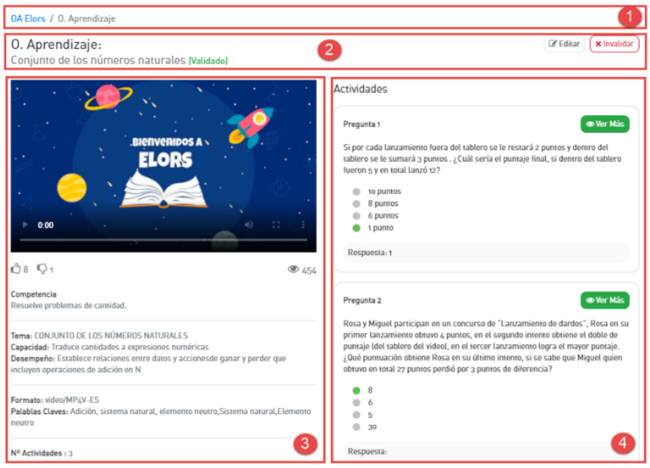

Fig. 1. Interface of the learning object and its activities. 1) Navigation history, 2) LO title, 3) LO and its metadata; 4) Activities related to the LO.

To access, first you must create an account in ELORS, the student enters the following web route https://unsa-elors.com/ (see Fig. 1). Once registered, the student will have the opportunity to navigate through the different activities and challenges. As the student interacts with the different learning objects and proposed activities, the navigation history is recorded, having access to the notification panel and progress in their level of achievement in learning, according to the activities performed (see Fig. 2).

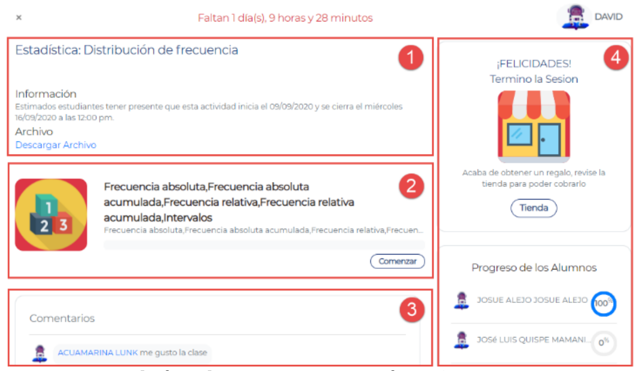

Fig. 2. ELORS platform learning session interface. 1) Learning session name 2) Learning object, 3) Learning session comments by learners; and 4) Notification panel and learners' session progress.

Once the answer is correct, the Platform will award virtual money, represented by diamonds, which will be accumulated to be exchanged for gold or to purchase items from the online store.

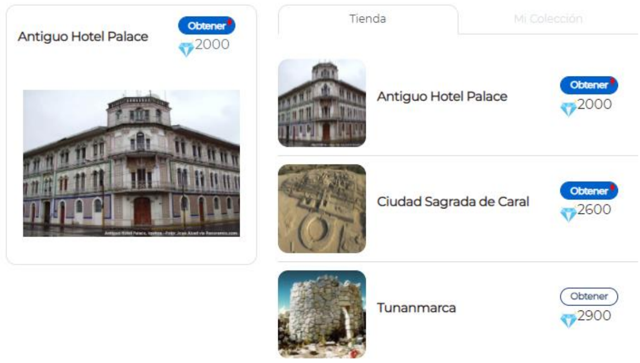

Fig. 3. Example of the virtual store interface on the ELORS platform, which are purchased according to the number of diamonds valued in each item.

The items in the Virtual Store are informative resources on historical sites that represent a part of Peru's history, national parks, and sanctuaries, and contain useful information for the student, such as: description, image, location, altitude, climate, tourist site, type of entrance, how to get there, and cost of admission.

To analyse all this interaction, metrics are available to perform the following tasks: data pre-processing, attribute selection, classification, regression, and clustering. In this case, Weka will be used as an open-source tool [23], with algorithms already implemented [24]. K-means is one of the unsupervised clustering algorithms, which attempts to group the data into K clusters to find the centroid of the cluster and group with it the closest data points. To correctly cluster the data points, the Euclidean or Manhattan distance can be applied [1]. For this purpose, the distance of each cluster element to its own centroid is calculated, the centroids are updated in such a way that the distance between the elements and their own cluster is minimized [22].

II. Methodology

The proposed online learning system through the ELORS gamified platform combines gamification technique, grouping and behaviour from the analysis of the metrics generated in the interactivity, which on the one hand is intended to measure the effectiveness of perceived usability with the achievement of the student in the ELORS platform and on the other determine the number of groupings based on 1065 interactions obtained from metrics based on online learning of 57 learning objects by the COVID- 19. For the realization of this research, information was taken from a database of a total of 51 users whose ages range from 12 to 13 years corresponding to the second year of secondary education of two institutions in the city of Arequipa-Peru. The approach is quantitative, descriptive, and correlational. The inclusion criteria included the students who made the most interactions on the platform. The application was carried out for two months.

III. Procedure

The study analysis procedure consists of a total of 3 phases:

A. Phase 1

TABLE I: Example of the Interface Showing the Hierarchy of Icons Considering the Amount of Student Experience on the Platform

	Icon	Name	Experience
1		TURQUOISE STAR	>0 EXP
		TURQUOISE SUPER STAR	>500 EXP
		SUPER GOLD STAR	>1000 EXP
		SUPER EMERALD STAR	>1500 EXP
5		SUPER STAR AMETHYST	>2000 EXP
		TURQUOISE NOBLE STAR	>2500 EXP
		SUPER STAR NOBLE TURQUOISE	>3000 EXP
		TURQUOISE ROYAL STAR	>3500 EXP
		SUPER STAR ROYAL TURQUOISE	>4000 EXP
		STAR LEGEND TURQUOISE	>4500 EXP

In reference to gamification, the gold obtained in their exchanges and the experience have been considered as variables. In the first case it is associated with virtual coins obtained by accumulating diamonds once they interact with the LOs and the problems they solve, to be exchanged for an icon proposed in the user experience (see Fig. 6); in the second case, experience is understood as the number of points obtained by developing their tasks and visualization interactions with the LOs (see Fig. 7). These give points to accumulate or in case you do not solve a problem correctly at the second attempt you receive a penalty.

TABLE II: Experience Gain and Diamonds According to Cognitive Demand and Learning Object Activity Alternatives

	Low cognitive demand	High cognitive demand
With alternatives	Gain x1 experience	Gain x2 experience
	Loses PENALTYx(-4) experience	Loses PENALTYX(-3) of experience
	Earn x1 of diamonds	Earn x2 diamonds
No alternatives	Gain x3 experience	Gain x4 experience
	Loses PENALTYx(-2) experience	Loses PENALTYx(-1) experience
	Gain x2 experience	Earn x4 diamonds

B. Phase 2

In the application of the exploratory technique of unsupervised learning using the K-means algorithm to find groups belonging to a category [25], the aim is to perform groupings based on the user's interaction with the platform, using the criteria of time, number of attempts, activity status, level of achievement and number of repetitions.

The classification process consists of the following steps:

1) The interaction data of the students with the LOs, and the gamified learning system were used. These metrics are extracted from the platform in excel record, for each interaction the total time consumed per activity of a LO, number of attempts to complete an activity, if all activities of a LO are complete or incomplete, level of achievement in 4 levels such as: start, process, achieved and satisfactory; and finally, the number of repetitions in the LO visualization are considered.
2) After collecting the data, the WEKA tool is used with the K-means algorithm from 2 to 10 centroids with a variation in the measurement of distance between the points and the centroid, the Euclidean and Manhattan measure were used. To analyse the sum of distances within each group as a measure of error, visualizing a graph for the appropriate choice of the number of centroids.
3) Finally, a report was generated from the number of centroids suitable for the data set.

C. Phase 3

In relation to behaviour, the perceived level of learning usability, the gold redeemed and collected by the student because of their interactions, the accumulated experience and the level of achievement obtained are evaluated. Corroborated by a survey of usability of the gamified educational platform, which contains in its first section the perception of the experience in use and the second contains two open questions that lead to describe their experience as a user and what could be improved from our proposal.

IV. Instrument

The usability instrument has been adapted from a study by [20] whose procedure consists of dividing 108 points among the individual categories of the 27 items to obtain the students' perceptions. The assignment of weights was obtained from the ratings for those usability variables and their sub-items: navigation in the system, learnability in the system, visual design, quality of information, instructiveness of the assessment and interactivity in the system. All items in the rating questionnaire were measured on a Likert scale and respondents were asked for their degree of agreement with the statements from 0 to 4 (0 = strongly disagree to 4 = strongly agree). To calculate the usability score for the e-learning system, the given weight (average of the subcategories) was multiplied by the site rating (the Likert score for each subcategory). Then, the calculated usability scores derived from the previous step were summed to form the overall usability value for the system. The overall usability value was evaluated by considering the six main usability categories in comparison to the students' use of the ELORS platform. Cronbach's alpha was used for the instrument, showing its reliability to be acceptable and high at 0.714 (see Table III).

TABLE III: CRONBACH'S ALPHA RELIABILITY

Cronbach's alpha	No. of elements
.714	20

This questionnaire includes two open questions to define new development opportunities or improve the existing system. What else would you like us to add in the ELORS gamified platform? What needs to be improved in the ELORS platform? Which are personal assessments that help us to understand the results found.

For data analysis, an Excel has been prepared with the levels achieved in relation to the frequency of use in interactions with learning objects on the platform through chi-square to analyse the likelihood ratio and to know the totality of interactions with the LO and the gold variable, experience and achievement levels, the Spearman coefficient correlation has been established.

V. RESULTS

This study investigated two ways to examine student behaviour on the gamified platform through the relationship of usability in the online learning framework to analyse whether there are significant differences in learning achievements in solving problems in mathematics and grouping models in correspondence to the interactions performed.

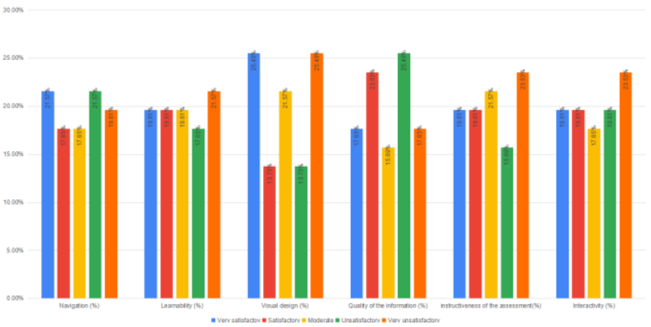

Fig. 4. Usability dimensions of the user experience in the ELORS platform.

The dimension of quality of information is the one that acquired the level of very satisfactory, followed by navigation in the system; the ability to learn in the system and the quality of information have obtained a score similar to the satisfactory level, in the moderate level all categories present a percentage higher than 25% except for the quality of information and in the unsatisfactory level the visual design presents a profile similar to the moderate in the perception of students and the very unsatisfactory is quite pronounced in the navigation of the system.

TABLE IV: LEVEL OF USABILITY OF THE ELORS GAMIFIED PLATFORM

USABILITY		
	F	%
Very satisfactory	11	21,57%
Satisfactory	14	27,45%
Moderate	14	27,45%
Unsatisfactory	10	19,61%
Very unsatisfactory	2	3,92%
Total	51	100,00%

Furthermore, 49% of the students express a positive perception of their experience as a user of the platform, 27% consider the interaction to be moderate and 23% show negative perceptions of their online experience.

In the two open-ended questions they categorized themselves by finding coincidences in their personal appraisals according to their experience as users.

TABLE V: RESPONSE TO OPEN-ENDED QUESTION NO. 28

28. What else would you like us to add to the ELORS gamified platform?		
	F	%
You do not want changes to the platform.	14	27,45%
Incorporation of more gamification mechanics.	13	25,49%
Accompaniment and feedback in problem-solving activities.	13	25,49%
Add comments and more interaction icons to search for more information.	8	15,69%
Accessibility to the platform and interactivity between teacher and student.	3	5,88%
Total	51	100,00%

TABLE VI: RESPONSE TO OPEN-ENDED QUESTION NO. 29

28. What else would you like us to add to the ELORS gamified platform?		
	F	%
No changes.	17	33,33%
Comprehension of statements, accompaniment and feedback on difficult problems	15	29,41%
Method of explanation.	8	15,69%
Speed and accessibility on the platform.	7	13,73%
Video quality.	4	7,84%
Total		100,00%

The main characteristic found in questions 28 and 29; those students do not wish to make any changes; they are satisfied with what has been designed. Followed by the fact that they want accompaniment and feedback to be able to solve the problems, due to the lack of decoding, they ask for help to be able to solve difficult problems and support with complementary formative materials to expand or as help to give solution to the statements raised and finally the accessibility to the platform in the sense of the delay to access, that it is more dynamic, that there are dialogues that flow in a communication and interactivity between teacher and student, as well as to improve the icons and to be able to change the colour of the screen or other applications.

In question 28, although they have diamonds in the accumulation of their points, they wish to incorporate missions, to increase the number of problems to accumulate more diamonds, to incorporate in the virtual store more objects to buy, as well as cooperative games that challenge other partners.

As for K-means, Fig. 7 shows the sum of distances within the group using from 2 to 10 centroids for the grouping of the students' interactions with the learning objects activities, such graph helps us to choose the appropriate number of centroids for the grouping.

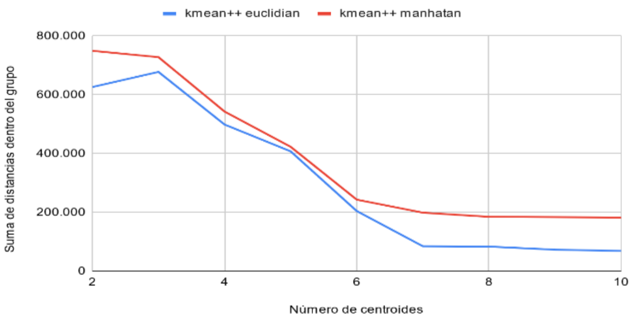

Fig. 7. Visualization of the sum of distances within the group using from 2 to 10 centroids.

To understand how the groupings are given in terms of time, number of attempts, complete and incomplete activities, level of achievement and number of repetitions from the records of student interactions, the appropriate choice was made for the number of centroids is 7, as interpretation groups #5 and #6 have an average number of attempts between 8 and 9, both make up 24%, In contrast, the remaining groups have an average number of attempts between 1 and 3, which make up 76%, in addition, groups #1, #3 and #7 are at an average achievement level of satisfactory, group #4 in achieved, group #2 in process and groups #5 and #6 in beginning, represented by 16% of the interactions while 84% of the interactions completed the activities of the learning objects.

TABLE VII: GROUPINGS OF USER INTERACTIONS ON THE ELORS PLATFORM

Attributes	C#1	C#2	C#3	C#4	C#5	C#6	C#7
Time	58,2	4,9	136,5	9,7	51,3	26,9	108
Attempts	1	3	1	2	8	9	1
Responded	1	0,993	0,991	0,994	0,23	0,95	0,89
State	C	C	C	C	P	C	P
Replay	0	0,25	1,09	0,26	0,32	0,54	0,39
Level	S	P	S	A	B	B	S
	G#1	G#2	G#3	G#4	G#5	G#6	G#7
Instances	212	160	119	181	34	221	138
Percentage	20%	15%	11%	17%	3%	21%	13%

State : Complete(C) or Incomplete(I)
Level : Satisfactory(S), Achieved(A), Process(P), Beginning(B)

To analyse the degree of usability of the various learning objects and significance with the level achieved by the students, show the next table:

TABLE VIII: CHI-SQUARE TESTS

	Value	df	Asittic significance (bilateral)
Likelihood ratio	1712,841	1557	,003
Linear by linear association	1,651	1	,199
No. of valid cases	1065		

That the chi-square test of likelihood ratio was performed; for categorical variables (the usability of the learning objects and the level reached by the students); from this it is evident that the probability of error (0.003) is less than alpha (0.05); therefore, it is deduced that there is a significant statistical association; in other words, the level reached by the students depends on the degree of usability that they perform with the learning objects.

TABLE IX: CORRELATIONS

Correlations			USA	GOLD	EXP	LOG
RHO DE SPEARMAN	USA	Correlation coefficient	1.000	3.55**	.453**	.434**
		Sig.(bilateral)		.000	.000	.000
		N				
	GOLD	Correlation coefficient	.355**	1.000	.842**	.810**
		Sig.(bilateral)	.000		.000	.000
		N				
	EXP	Correlation coefficient	.453**	.842**	1.000	.962**
		Sig.(bilateral)	.000	.000		.000
		N				
	LOG	Correlation coefficient	.434**	.810**	.962**	1.000
		Sig.(bilateral)	.000	.000	.000	
		N				

USA : Usability of learning objects
GOLD : Gold obtained
EXP : Experience gained
LOG : Achievement obtained
Correlation is significant at the 0.01 level (bilateral).

Spearman's RHO test shows that, according to the use of the different learning objects, this is significantly related to the amount of gold accumulated (0.000), experience (0.000) and achievement obtained (0.000); likewise, a level of relationship with prevalence to moderate is assured.

VI. DISCUSSION

The success of any gamified platform depends largely on the motivation and user experience, in this case both usability and behaviour have a preponderant level between satisfactory and achieved, there being a significant statistical association; that is, the level achieved by students depends on the degree of usability they perform with the learning objects. If an interface is poorly designed, users feel lost, confused, or frustrated, making its use difficult [2].

From the analysis of the usability instrument the dimension of information quality was the most important in the six dimensions, followed by the level of navigation of the system. Finding a similar finding in the study of [20], where the interface provided allows the student to feel comfortable. The visual design is the one that has obtained the greatest dissatisfaction, in the open questions were found as personal factors coincidences of wanting to change the colour of the screen, that dialogues are opened between the platform and users to maintain a type of communication and more attractive icons that attract attention and that will allow a reorientation in the design of our proposal,

In this sense, the perception of the users towards the platform is acceptable, but both in the instructional dimension of evaluation highlights its moderate value and in their personal appreciations they showed coincidence in the accompaniment and feedback that allow to have a more direct contact between teacher and student to help them in their learning process, since they denote that there are problems in the decoding of the statements, they require more questions to understand, as well as to look for more theoretical support and strategies to solve the problems, sustained in that a minority of students remain in the beginning or process, that they do not get to finish their activities and take less time and more attempts. In contrast to what was presented, it was found that students with a higher degree of knowledge of the subject make moderate use of the platform, while those with poor grades make an exhaustive use to level the grades, thus creating an over dimensioning effect of this variable in the results [25].

In reference to the user experience and the grouping model of the students' behaviour in the gamified educational platform through the k-means algorithm, it allowed grouping the students, finding 7 groups of participation located in two centroids, one by the number of attempts and the other sustained by the interactions. In the case of the first one, there were from one to three attempts, achieving a little more than three quarters to optimize the time in their interactions. Denoting those educational resources through e-learning platforms impact the success of a student [26], as well as the availability of the platform, the quality of interaction and the quality of service [27]. In the second case only, a quarter did not achieve the expected learning, remaining at a starting level, which would lead to a deeper study to know their difficulties, more linked to not being able to solve the proposed problems. Inevitably, understanding the content of a problem is fundamental, and it depends on each student to translate it into mathematical language and to be able to interpret the mathematical result [28].

Within the limitations, the results show that users in the dimension of interaction in the platform system at the time of entry relate it to speed, accessibility and mastery evaluating in terms of moderate, sustained in their personal assessments that the interface should be more agile. In such a way, that users have the tendency to want to easily search for the content of the data to interact in it [29], in our case due to the problems pointed out, in addition to the equipment available to the students from their homes, it was necessary to add the technical assistance by the teachers for the creation of e-mails to access the platform so that they can interact in it. But, on the other hand, the positive side was also analysed in this time of confinement, resulting important to validate the experience of the use of technology and pedagogy that allowed motivation, collaboration in authentic activities to improve the students' experience [3].

Among the recommendations, the following are proposed: Consistent navigation and accessibility, content search functionality through a recommendation system that leads to a personalization of learning, allowing them to expand or reinforce what they have learned, and enable notifications based on dialogues that allow them to feel accompanied in the online learning process. This will lead to the platform's potential to optimize learning in mathematics. Likewise, to increase gamification strategies that allow a greater accumulation of diamonds, in addition to analysing the preferences for the accumulation of gold stars that students made among the other alternatives and that served as a stimulus for their interactions.

VII. Conclusions

This study sought to establish the relationship of perceived usability in relation to user behaviour based on the gold collected, experience and achievement, obtaining a significant correlation with a moderate tendency in online learning. It shows that special emphasis is required on new forms of communication to interact in an attractive and effective way with dialog interfaces and conversational agents that allow users to feel a friendly accompaniment in their virtual learning.

In reference to the metrics and their grouping, these were manifested in two models based on the number of attempts and the level of interactions that allowed us to see the students engaged with the activities developed online and those who did not manage to complete them. In addition, low levels were shown in relation to the time and status of the activity.

Online learning has become an area of great interest, which presents challenges of adaptability, efficiency, effectiveness, personalization, evaluation, among others, that allow an effective and lasting interaction, especially in programming for the area of mathematics, which is not adverse in this research work, which seeks to evaluate the ways, methods and means to achieve a favourable acceptance of users and try to achieve a personalization of learning.

Future work could focus on using this platform in a face-to-face teaching context to analyse perceived usability and sustainability, as well as preferences when changing virtual values, such as their level of participation and engagement.

Conflict of Interest

We certify that there is no actual or potential conflict of interest in relation to this article.

Author Contributions

Fabiola Talavera-Mendoza formulated research goals. Carlos E. Atencio proposed the methodology; David A. Deza developed the results and started the manuscript. Finally, Alexander R. Cayro and Henry del Carpio verified the manuscript critically for important content and presentation of the published work.

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