Improving the Design of Virtual Learning Environments from a Usability Study

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Abstract. Usability as an area of knowledge of Computer Science closest to the user, has seen enhance their interest and development in recent times, due to the diversity of devices and forms of interaction. At the same time, educational institutions, aware of the potential existing in new technologies, and the disruption caused, invest their resources in the implementation of virtual learning platforms. In this investment, they seek diversify in the tools that allow the development of new teaching strategies, which are ubiquitous and continuous, adaptable to the needs of the user. In this context, a usability study is carried out, sustained in the method of inquiry with the questionnaire technique, following the proposal of Ferreira & Sanz in 2009, measuring the parameters of Satisfaction, Learning, Operability, Attractiveness, Content and Communication. The best results are obtained in the Learning and Content indicators, and with lower scores the Operability, highlighting in the latter the low value in the Accessibility and Availability indicators. According to the results obtained, a proposal for improvements is proposed, in order to achieve a greater degree of usability in the mentioned environment. Finally, these improvements are implemented in the case study, making a new evaluation of users in order to validate the improvements made.

Keywords: Usability · Higher education · LMS · Design

1 Introduction

Several of the human activities require the management of large amounts of information in relatively short times, as well as the constant decision making, to be quickly and efficiently allow the development and advancement of all types of entities around the world for the benefit of humanity. The highlight of this accelerated change is the migration of the various services to Inter-net; supported by technological platforms that eliminate spatial and temporal barriers allowing access to millions of users to the information they contain. One of the fields that since many years ago it has adopted as a strategic ally to new technologies, is the educational field, which through large platforms supports the teaching-learning process.

Therefore, the need to develop computer applications centered on the user is evident. In this sense, usability has become a factor with a more important role even than the information architecture itself or content management and increasingly arouses greater interest in the community of developers, who emphasize rigorous processes of evaluation during and after development. Based on these aspects, the research aims to: a) Carry out a usability study of the UTPL Learning Management System (LMS) that was based on different parameters that allow identify the aspects that negatively affect the usability conditions of the platform; b) Formulate alternative solutions for the LMS platform to guarantee, favor and facilitate the teaching-learning process for teachers and students; c) Implement the improvement proposal in a test site to determine the feasibility of these being moved to the real operating environment.

The report begins with a general theoretical revision and state of the art on the Usability in higher education fields, with several LMS platforms, with greater emphasis on the MOODLE platform. It also analyzes emerging methodologies, considering the methods, techniques and parameters used by researchers in the area to carry out this type of evaluation. Next, the study conducted with the specific EVA of the UTPL is presented as a case study, from the model proposed by Ferreira and Sanz [1, 2] at the Universidad de la Plata. Then, the proposal of improvement of conformity to the representative problems revealed during the evaluation is shared, with the purpose of reaching a greater degree of usability within the environment. At the end, its implementation is detailed in the Moodle 1.9 platform hosted on a test server.

2 Usability

2.1 Theoretical Framework

Usability "studies the essential characteristics that a software or computer application must have in order to guarantee easy access to any person regardless of the technology available, and the knowledge they have about the use of ICT [3]. Bevan [4] shares a fairly specific definition, explaining how the usability and acceptability of a system or product for a particular class of users that perform specific tasks in a specific environment, where ease of use affects performance and user satisfaction and acceptability affects whether the product is used or not". Torres-Carrión [5], explains the great coverage of Usability, which evolves as a sub-area of UX, with great consideration in the scientific field for the design of quality; explains in [6] hat the study of Usability depends not only on the interaction system, but on how it has been validated and what the objectives were, and in the educational field it also has as premise that the learning attributes will vary between people, and this variable extends its value if we also consider the context from which it is evaluated.

The International Organization for Standardization (ISO) has also been concerned with providing technical and scientific coverage to this area of science. In the general field of quality in the Software industry, the ISO/IEC 9126-1:2001 standard is presented, later revised in ISO/IEC 25010:2011 (updated to 2017), where the key quality factors are established, including among them usability, and it is defined as a *subset of quality in use consisting of effectiveness, efficiency and satisfaction, for consistency with its*

established meaning [7]. In the field of user ergonomics, as subfield of Human Computer Interaction (HCI), the ISO/DIS 9241-11:2017 standard is presented, where Usability is not defined like as an attribute of a product, although appropriate product attributes can contribute to the product being usable in a particular context of use, it is a more comprehensive concept than is commonly understood by "ease-of-use" or "user friendliness" [8]. Usability is not just another attribute of a system, but one of the key attributes that can make the difference between success and failure of the product; because *it is intimately related to the user's perception of the quality of the system; the internal algorithms or the definition of the architecture can be excellent, but the user does not have visibility of that, but of the interface with which he interacts* [9]. For the context of this study, the definition closest to the User Centered Design, framed in the HCI field, is considered as close.

2.2 Methods for the Evaluation of Usability

The main methods for the evaluation of usability derive from *User Testing* [10, 11], *Heuristic Evaluation* [12] y *model-based methods* [13]; those related to the first case, refer to empirical evaluations from the hypothesis, which implies the detail of dependent variables and indicators.

The three measurable usability attributes defined by ISO [8] are:

- **Effectiveness**: accuracy and integrity with which users achieve the specified objectives.
- **Efficiency**: resources spent in relation to the accuracy and integrity with which users reach the objectives.
- **Satisfaction**: absence of discomfort and positive attitudes towards the use of the product.

According to the model of measurable attributes of Nielsen [14], usability has the following attributes: ease of learning, efficiency, ease of recall, errors and subjective satisfaction. Rober Stake [15] proposes nine evaluation methods grouped by purpose: exploratory, predictive, formative and summative. The methodology proposed by Ferreira and Sanz [1, 2] belongs to this field, and that is the basis for the development of this proposal.

Heuristics usability are a widely accepted method. Mtebe and Kissaka [16] presents a heuristics usability that consolidates interface usability, didactic effectiveness and motivation to learn. Other researchers design an instrument on the basis of the general criteria for the heuristic evaluation proposed by Nielsen, as well as on international standards, guides, and recommendations for software quality (ISO 9241 and ISO 9126), with encouraging results for applying the usability evaluation instrument to Metacampus, an LMS developed by and used at the Virtual University System in University of Guadalajara [17]. Almarashdeh et al. [18] evaluate their prototype by six experts whom have good experience in different fields (LMS development, system quality, software engineering and distance learning) to show their satisfaction with features and requirements.

The User Affective Experience (UAX) is considered an emerging field in HCI [6, 19], with extended metrics from UX and Usability that take interaction data from various sources: observational, sensors and algorithms. Ulbricht et al. [20] evaluate the emotion component on usability human computer interface. To evaluate LMS's HCI describe methods and techniques used to evaluate HCI using Usability Tests with emotions and then validate them in the WebGD LMS. Pireva et al. [21] analyze user behavior in LMS and MOOC, using facial expression software to find seven emotional engagement attributes and three sentiment engagement attributes; as a methodology, they design an experiment with different tasks that each subject has to perform. Phongphaew and Jiam-sanguanwong [22] measure 5 usability attributes; learnability, efficiency, effectiveness, memorability, and satisfaction, as a relationship of each usability attributes and emotional responses of user in order to understand the relationships of these two evaluation methods.

Artificial Intelligence (AI) is also making its contribution to this field of science. So, using data mining from 421 comments written by university students who frequently use an LMS, Jiménes et al. [23] propose an approach based on text mining techniques, which allows quick identification of usability and functionality issues. It has mentioned the most relevant methods currently applied in the study of Usability. There are several emerging methods that make use of look tracking technologies, counting clicks, gamification, degree of user attention in each option, among others, which continue to give dynamism to this area of science.

2.3   Related Research

HCI is an area of multidisciplinary science, and therefore it is necessary to carry out a broad study from different sciences; this has been inherited in Usability as one of its subfields. Freire [24] details a great diversity of points of view, including researchers from different scientific areas such as Ergonomics, Computer Science, Design and Education. Psychology is also an area of science to consider, given the imminent user behavior, as a center of the study of Usability.

Systematic Reviews of Literature About Usability in LMS

The efforts made in the search for Usability studies in LMS [24–26] have different approaches and give us a first view of the scope of this field of science. Freire [24] embraces three dimensions, namely the methods, models and frameworks that have been applied to evaluate LMS, including also the main usability criteria and heuristics used; their results show a notorious change in the paradigms of usability. The main criteria adopted in E-learning evaluations originated in criteria already researched by Informational Ergonomics, and the three main methods and techniques used (in the last 30 year $<=$ 2012) are: (i) system performance evaluation, (ii) of user performance and (iii) the evaluations of the dialogs between users and systems.

Aydin [26] explore trends, gaps, and issues in the literature of the usability of Learning Management Systems (LMS). Their analysis revealed several gaps: *(1) engineering students have not been the main focus of research in any studies, (2) there is no research that compares usability of LMS between different academic disciplines, (3)*

there is no modeling effort for understanding if engineering students and instructors need different LMS design than other disciplines, (4) primary framework development for evaluating LMS has declined, (5) discount usability methods (heuristics) have been mostly preferred for the evaluation of LMS ignoring effectiveness and efficiency performance measures related to LMS usage, (6) there are very limited studies incorporating usability design with instructional and accessibility design, (7) there are very limited studies investigating LMS usability with regards to occupational training, (8) there are many researchers who mentioned the significance of research on usability of mobile e-learning platforms. These results support the problems raised in this research.

In addition, Nakamura et al. [25] characterize the usability and UX evaluation techniques in the context of LMSs, checking a total of 62 publications (2004–2016), in which they identify the techniques used to evaluate the usability and UX of LMSs and their characteristics such as its origin, type, performing method, learning factors, restriction and availability. From the research question "*Which usability and UX evaluation techniques were applied on Learning Management Systems and how have they been used?*" propose 11 sub-questions, where they stand out for our purpose: Technique type (Inquiry 51,92%; Testing 33,65%; Inspection 27,98%), Performing method (manual 90,38%; automatic 7%), Evaluation focus (Usability 69,23%; Usability and UX 28,85%; UX 1,92%); Feedback (No 100%, Yes 0%), Investigation type (Case Study 25,86%; Survey 25,86%; Controlled Experiment 17,24%), Platform used (Desktop/Web 79,31%; Mobile 17,24%). Contrary to what we have seen in this study, changes in the platform are presented here and a complementary study is presented to support the validity of the changes.

Usability for Courses Design

Pástor et al. [27] proposes a methodology for creating e-learning design patterns, development a catalogue of ten design patterns for the creation of online courses in a VLE, articulating pedagogical methodologies used in virtual education. To validate, two evaluation processes were carried out: *the first one to measure ability to design online courses with the teachers and the second one to measure the usability of the online courses with the students*. Lai and Lin [28] analyzing the difficult tasks for expert (8 teaching assistants who have past Moodle teaching experience) and novice users (8 teaching assistants with non-Moodle experience); they carried out 18 usability tasks, post-task interviews, and finally a survey with 25 questions. Qualitative research provides a significant contribution, supported by techniques such as questionnaires, interviews, systematic observation and study of historical documents related to processes and the user.

Results gathered in usability research conducted among students confirm that development of eLearning systems needs to have learner in the center of development process [29]. In an empirical-based study, Harrati et al. [30] explore how university lecturers interact with an e-learning environment based on a predefined task model describing low-level interactions. From user feedback, via experimental System Usability Scale, results reveal that the evaluation must be fulfilled in tandem with analyzing the usage metrics derived from interaction traces in a non-intrusive fashion, and that these are not

a sufficient measure to express the true acceptance and satisfaction level of lecturers for using the e-learning systems.

Usability in LMS for Higher Education
Higher Education institutions have been the pioneers in implementing interaction platforms, so it is essential to know the actual work related to the area. Thus [31] assess the usability of the Jusur Learning Management System (LMS) that is used in higher education in Saudi Arabia. Nine factors have been incorporated into a survey to evaluate the system: content, learning and support, visual design, navigation, accessibility, interactivity, self-assessment, learnability, and motivation. Kurata et al. [32] evaluate the effectiveness of the LMS, considering variables in the LMS design model, from the pedagogical approach, the usability and the satisfaction aspect of the user interface; the result shows that LMS is an effective tool to facilitate learning in an undergraduate engineering program in the Philippines, and that it could be made more efficient by adding collaborative learning tools for students.

As one of the emerging areas of Higher Education, there is Distance Education, now closely related to Online Education, which has been boosted since 2011 in an open manner with MOOC and REA. This field [33] describe the process of developing and evaluating the Moodle-based mobile Learning Management System (LMS) application called Student Centered e-Learning Environment (SCeLE). They implement the application with user-centered design basis, at the last phase we evaluated the application using usability testing and system usability score (SUS). Almarashdeh et al. [18] measure the usability of a DLMS prototype based on user's requirements, applying verification method using heuristic evaluation (experts review) to evaluate the prototype interface.

Usability in Several LMS
The availability of LMS in the market is increasing. This has required area researchers to evaluate various LMS platforms globally. Thus, Phongphaew and Jiamsanguanwong [34] identify the interface issues of myCourseVille by using usability evaluation method associated with student's interface and teacher's interface. The myCourseVille is a LMS that use in many universities in Thailand to support teachers and students to manage their class activities. Lalande and Grewal [35] from usability metrics compare two Learning Management Systems (LMS): Blackboard and Desire2Learn; they have as input the number of mouse clicks necessary, number of pages traversed, and data fields inputted. Okike and Morogosi [36] evaluate the use of Moodle and Blackboard from academic disciplinary domain perspectives, through quantitative research approach to conduct a survey study using 67 university lecturers (43 use of Blackboard, 11 make use of Moodle, and 13 do not use either platforms); both platforms are convenient for the creation and distribution of teaching materials, course assessment, communication and collaboration between users. In addition, from a logistic regression analysis, users have a greater probability of using Blackboard (Odd Ratio = 4.96) than Moodle (Odd Ratio = 1.00).

Usability for MOODLE

This is the base platform on which the proposed study focuses. For this LMS, Karagiannis and Satratzemi [37] present a usability study on a dynamic framework that adapts to the user, showing improvements in this adaptation in Moodle with respect to the standard version. Ifinedo et al. [38] explore the effects or roles of usability factors and external support (i.e., teacher and peer support) on undergraduates' use outcomes of Moodle in a blended learning environment. For this purpose they conducted a cross-sectional survey and collected data from 126 undergraduate students attending a university in the Maritime region of Canada; the result show that usability factors have positive effects on students' use outcomes; contrarily to predictions teacher and peer support did not. These results are relevant in terms of the contribution that Moodle as a tool can give to the didactic process in the classroom.

3   Evaluation Methodology of Usability for Study Case

The evaluation must be a planned and carefully applied process; it can go from the application of empirical methods as discussed in Sect. 2.2 with real users, to other more refined methods with domain experts, as established in Fig. 1.
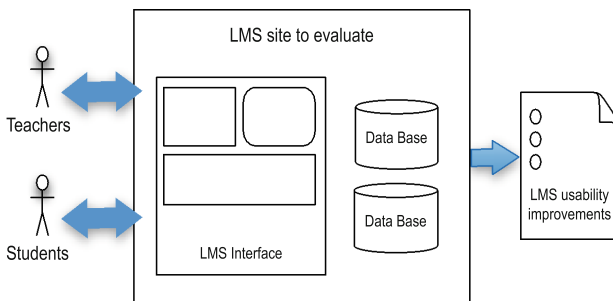
Fig. 1. Participants in the evaluation process

As it is an evaluation of usability from the user's perspective, two categories of users have been considered, who normally maintain a constant interaction with the UTPL LMS: **Teachers** and **Students**, with whom prior contact was established, obtaining their consent and commitment to participate in the study.

3.1   Definition of Methods-Techniques and Evaluation Parameters

Taking into account the restrictions and the variety of tasks that are carried out through the LMS, the evaluation is based on the study of the tasks considered most representative. The method of inquiry supported by the questionnaire technique was used.

In the evaluation of usability are important aspects such as *ease of use, effectiveness, efficiency, ease of learning, user satisfaction, accessibility, consistency, among others. All these concepts are related to the usability of the Web site* [2]. According to this

description the parameters used to measure the LMS usability through a questionnaire are shown in the Table 1.

Table 1. LMS usability evaluation parameters

Parameter	Description
Satisfaction	Utility Speed
Learnability	Ease of learning Help
Operability	Ease of Navigation Ease of use Availability Error tolerance Accessibility
Attractiveness	Attractiveness of the interface Personalization
Content	Credibility Reach
Communication	Control of communication Forms of messages

3.2 Data Collection

The data collection was carried out through the application of the online questionnaires to students and teachers, through Google Drive forms. In the case of students in the face-to-face mode, the application was carried out directly. It is important to emphasize that the representative sample to which the questionnaires were applied consists of 160 students and 65 teachers. The information obtained from the evaluation process is the basis for carrying out the corresponding improvement proposal, in the aspects that reflect LMS usability problems and its implementation is feasible.

3.3 Results Measurement

The nature of the items of the questionnaires used allows obtaining information in terms of percentages, for this reason the interpretation and presentation of the results is based on an assessment scale as indicated in Table 2. These items allow determining the level of compliance of the attributes evaluated. The final score of each attribute is obtained by calculating the average weight of the questions involved with the evaluated attribute. In case the score has a fractional part, rounding is applied.

Table 2. Scale of assessment of results

Indicator	Weight	Range
Optimum	4	76% - 100%
Acceptable	3	51% - 75%
Improvable	2	26% - 50%
Critical	1	0% - 25%

According to this scale, an indicator of a good level of compliance is Acceptable or Optimal and reveals the need to make an improvement in cases in which it is located in Critical or Improvable.

4   Results

Once the surveys for the data collection were applied, the tabulation and presentation of the results were carried out (see Table 3) in which the different parameters selected for the evaluation can be differentiated and their location according to the rating scale proposal in Table 2.

Table 3. Results of the usability evaluation of the UTPL LMS

Parameter		Score	Assessment
Satisfaction	Utility	3,5	Optimun
	Speed	2	Improvable
Learning	Learnability	3,2	Acceptable
	Help and Documentation	3,4	Acceptable
Operability	Ease of Navigation	3,67	Optimun
	Easy to use	3	Acceptable
	Availability	2	Improvable
	Error tolerance	3,5	Optimun
	Accessibility	2	Improvable
Attractiveness	Attractiveness of the interface	4	Optimun
	Personalization	1	Critical
Contents	Credibility	2,67	Acceptable
	Scope	3	Acceptable
Communication	Communication control	2,43	Improvable
	Forms of messages	2,5	Acceptable

5 Proposal

From the results obtained, it is clear that the aspects related to usability that should be considered in the improvement proposal are the following:

- Communication control (improvable)
- Interface customization (critical)
- Accessibility (improvable)
- Speed (improvable)
- Availability (improvable)

According to certain aspects that have been determined in the investigation, these parameters are considered as problems due to certain factors. The proposal focuses on incorporating functionalities (use cases) into the platform to solve the usability problems revealed in the research. Table 4 establishes the relationship of the problems identified with the proposed solution.

Table 4. Problems and solution alternatives

Problems	Use Case	Solution
Communication	Use chat	Integrate Moodle chat activity and / or plugin for the Chat Console block.
	Format message text	Configure the use of the HTML editor.
	File upload	Upload files to the server and access through hyperlinks
Accessibility	Customize environment	Integration of the plugin for the Accessibility Block
Personalization	Customize environment	Allow customization using themes for the user interface.
Speed		Services in the cloud, ongoing project by the UTPL.
Availability		Services in the cloud, ongoing project by the UTPL.

5.1 Validation of Improvement Proposal

For the implementation of the mentioned usability improvements it was previously necessary to execute the following tasks:

- Configuration of a test environment, consisting of the Web Server, DBMS and PHP and installation of the Moodle 1.9 platform, because it is the version that currently supports the UTPL LMS.
- Analysis of the operation of the Moodle platform and comparison with the LMS of the UTPL, in the administration options of the site to determine the appropriate configurations.

- Creation of a course and test users that allow operating in the Moodle environment.
- Implementation of the necessary configurations in the platform to achieve the objectives of the proposal.

At the date of the study, the UTPL uses the Moodle 1.9 platform as the basis of its Learning Management System. Many adaptations have been made in the original site, although several Moodle configurations are preserved, such as: the navigation bar, the components in panels located in the sidebars.

The next step, before establishing a configuration to carry out the implementation was an analysis of the structure of the platform, fundamental knowledge for its operation, following the structure shown in Fig. 2.
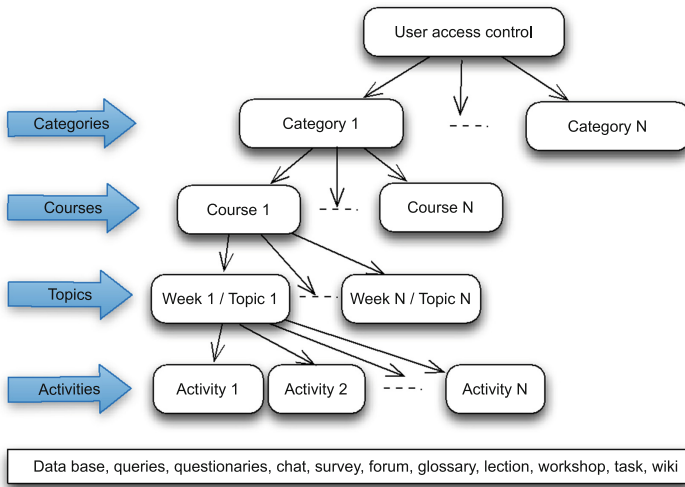
Fig. 2. Structure of the Moodle platform. Adapted from González [39]

In order to demonstrate the feasibility of operating with the functions that users consider necessary to facilitate their work within the LMS, it is necessary to configure an extended test version from the running version in the UTPL LMS, with full access to configuration, and access roles both administration and operation. As part of these activities, these tasks were carried out:

- Creation of the course
- User registration on the site and definition of roles
- Verification of the operation of the test course

Once the test operating environment for the installation, review, implementation and testing of the Moodle platform has been configured, the functionalities are incorporated and the appropriate configurations that satisfy the solutions proposed in Table 4 are established.

5.2   Test Results

The test plan fundamentally establishes the objectives that need to be achieved in accordance with the proposed solutions, the scope of the tests, the elements that will be tested on the platform, the requirements, procedures for registering the tests and the restrictions to which hold on. According to the plan, the testing process has been carried out in 3 stages: functional tests by the site administrator, functional tests by the users and acceptance tests. The population selected for this evaluation is made up of: Administrators of LMS (5), Teachers (10), and Students (20). The results of the functional tests and acceptance tests performed according to the plan established for the effect are presented.

In the functional tests, the obtained results can be evidenced that in regard to the access and use of the environment, as well as in the Communication, no functional problems have been detected. With regard to personalization and Accessibility, it was found that the functionality is somewhat affected by the response times of the site. However, the general results provided values that are located in each case, in operating percentages of 80% to 100%, and 20% or less error that have served to perform a general review of the platform (Fig. 3).
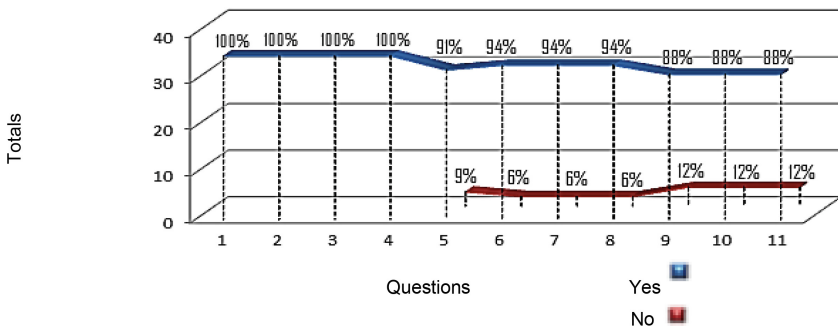
Fig. 3. Overall results of students functional tests

The results of the acceptance tests show a high degree of acceptance. Regarding Communication, the Messaging service with HTML has an acceptance of 94%, while chat sessions are 88% level and 85% for chat console, because some teachers consider it a distraction. The integration to the platform of the accessibility block; it has an acceptance level of 88%. In this case, the values are between 85% and 100% acceptance, demonstrating that it is justified that these functionalities are integrated into the LMS (Fig. 4).
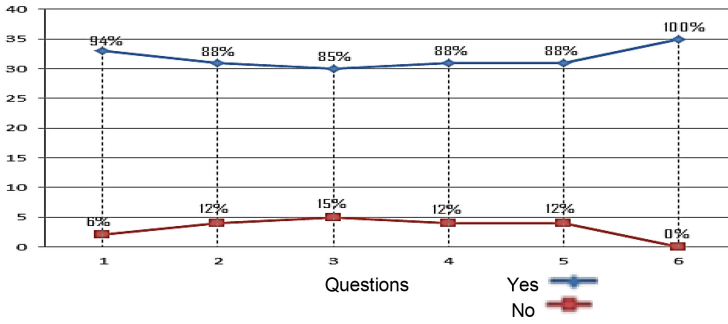
Fig. 4. Overall results of teachers functional tests

6 Conclusions

The development of this research work has allowed the acquisition of numerous knowledge and valuable experiences related to usability, a topic of interest at present in which humanity is virtually daily connected to the Internet to perform various activities. The objectives and level of knowledge of the users complicate the panorama of this technological environment. This is enough reason for the development of websites based on a user-centered methodology to be an alternative, a topic that has merited attention in various sectors. The study conducted on the subject has allowed to reach the following conclusions:

- A study case of evaluation of the usability of the Learning Management System LMS of the UTPL, which was carried out with the participation of real users of the platform (teachers and students) in order to obtain real results.
- A set of metrics and a scale was define that mark an initial diagnosis of usability for this type of platforms quantitatively, which was apply and validate in a study case.
- The improvement proposal was raised based on the analysis of the results obtained, the same ones that reveal those attributes that are located at an improvable or critical level, such as Communication, Personalization, Accessibility, Availability and Speed, which can be solved with a appropriate configuration of the platform and in the last two cases with the intervention of the UTPL through the cloud services project.
- The implementation allowed a post-study of the platform, determining that it offers a variety of alternatives to integrate sufficient and necessary functionalities to improve usability; this is corroborated by post-implementation tests that demonstrate its functionality with results above 80% and acceptance levels above 85%.

The favorable results of the usability study do not depend only on the platform available in the institutional web portal. Although it is true that it is the main factor, in platforms with a high degree of parameterization, it also depends to a large extent on the policies established by the Educational Institution that adopts it, the administrators, the teachers and the students. In this way, the range of possibilities offered by the LMS

can be adequately and converted into an efficient and effective environment that guarantees satisfaction in its use.

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