MOODLE USABILITY ASSESSMENT METHODOLOGY USING THE UNIVERSAL DESIGN FOR LEARNING PERSPECTIVE

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ABSTRACT

The application of the Universal Design for Learning framework favors the creation of virtual educational environments for all. It requires the development of accessible content, a usable platform and the use of flexible didactics and evaluations that promote the constant motivation of students. The present study aims to design a methodology to evaluate the usability of the Moodle platform based on the principles of Universal Design for Learning. It recognizes the importance of accessibility, usability and the availability of Assistive Technologies in an inclusive virtual education that meets the needs of students. We developed and applied a methodology to assess the level of usability of Moodle, taking into account that they integrate Assistive Technologies or are used for MOOC contexts. We employ the mixed design research framework to evaluate a MOOC-type educational program. We conclude that Universal Design for Learning principles and guidelines are positively valued by students and have a positive impact on certification rates.

Keywords: Distance education and online learning, evaluation methodologies, lifelong learning, special needs education, teaching/learning strategies.

INTRODUCTION

It is essential to consider inclusive Virtual Education as a high-impact strategy to improve the coverage, relevance and quality of education at all levels and types of training. Virtual Learning Environments (VLEs) are web-based systems that facilitate online communication, collaborative work, the sharing of various types of resources or educational materials, assessment and student monitoring (Cassidy, 2016; Caprara & Caprara, 2022). Designing VLEs for all means recognizing different populations, including students with functional diversity or disability, so not only the characteristics of the platform must be kept in mind, but also the particularities of the pedagogical materials, which can become barriers to learning if not properly designed (Crisol, Herrera and Montes, 2019; Fermin-Gonzalez, 2019; Vilaverde, 2020; Chidiadi, 2024). Likewise, it must be recognized that these students face technological, pedagogical and attitudinal barriers, negatively affecting their academic performance and success, therefore educational environments accessible to all must

be guaranteed since this transformation contributes to a more just society (Ntombela, 2020). Inclusive education and digital literacy are two key elements in quality education. UNESCO (2022) emphasizes that the teacher must recognize the appropriate use of technologies in harmonizing the needs and particularities of each student. It is important to formulate and implement a wide range of learning strategies that respond precisely to the diversity of students. One of the paradigms that is gaining more strength every day, showing successful experiences at different educational levels, is the Universal Design for Learning (UDL). According to the Center for Applied Special Technology (CAST) (2018), UDL focuses on the design of flexible and versatile educational curricula, with diverse materials and media so that everyone has access to learning. UDL takes advantage of the great benefits of technological media, such as: versatility, transformation capacity and generation of connections. E-learning offers a wide range of possibilities to promote Education for All, which is why it is widely used.

According to the World Health Organization (WHO) (2018), Assistive Technologies (AT) are systems and services related to software that provide help and support, allowing people to lead a productive and independent life and to be part of the social, labor and educational environment.

Accessibility and usability promote the possibility for users to use learning platforms and educational digital content according to their needs, participating equitably in digital educational environments. Designing virtual learning environments for all implies recognizing different populations, including students with functional diversity or disabilities, so it is necessary to keep in mind not only the characteristics of the platform, but also the particularities of the pedagogical materials.

This research developed as a doctoral thesis, provides a methodology for the evaluation of usability in LMS (Learning Management System), Moodle v.2.x and v.3.x environments, which could well be transferable to other LMS environments, since it seeks to improve the VLE, in terms of usability and accessibility for all. It is important to mention that the v.2.x platform instance used corresponds to that used by the University of Granada in Spain, while the v.3.x instance is the one used at the Universidad del Atlantico in Colombia, for the academic year 2019/20. As part of the evaluation, the design and use of a MOOC training action (implemented in the Moodle v.3.x platform) has been provided, incorporating the opinion of users in their different roles and recognizing the importance of education for all and universal learning. This experience opens the way to verifying the applicability of UDL principles as a key element to offer virtual educational programs for all, recognizing the importance of accessibility and usability of AT-supported environments.

Education for all, or Inclusive Education, is an educational approach that values diversity as an element that enriches the teaching-learning process and therefore the development of the human being. It is associated with values such as participation, equity, equality and justice, which transcend the attitudes of teachers, students and the community in general (Haug, 2017; Robinson-Pant, 2020; Page, Anderson & Charteris, 2023). Inclusive Education promotes learning for all, including students with special educational needs, by enabling equal opportunities, removing barriers, and through presence, participation and progress in physical and virtual contexts. Students with special educational needs require additional or different support to what is normally available in the teaching-learning process for other individuals of similar age (Florian, 2019).

Authors such as Kent, Ellis and Giles (2018), Rogers-Shaw, CarrChellman, and Choi (2018) and Oswald, Adams and Hiles (2018), point out the importance of the universal design approach in e- learning, arguing that it provides adaptations that favor the academic performance of students, especially those with special educational needs. The UDL framework invites the design of learning environments commensurate with the increasing diversity of learners encountered in online courses (Rogers-Shaw, et al., 2018).

The three principles of UDL consist of promoting multiple forms of representation, expression and involvement (CAST, 2018). Figure 1 graphically presents the three UDL principles and their guidelines.

UDL is an approach that addresses the challenge of making all students expert learners and is widely used at various levels, including university (Dickinson and Gronseth, 2020; Frumos, 2020; Griful-Freixenet, Struyven and Vantieghem, 2020; Bray et al, 2023). When choosing UDL implementation strategies, it is recommended that its principles be introduced gradually, starting by replacing undervalued activities to keep students and teachers excited about learning (Rao, Edelen-Smith and Wailehua, 2015).

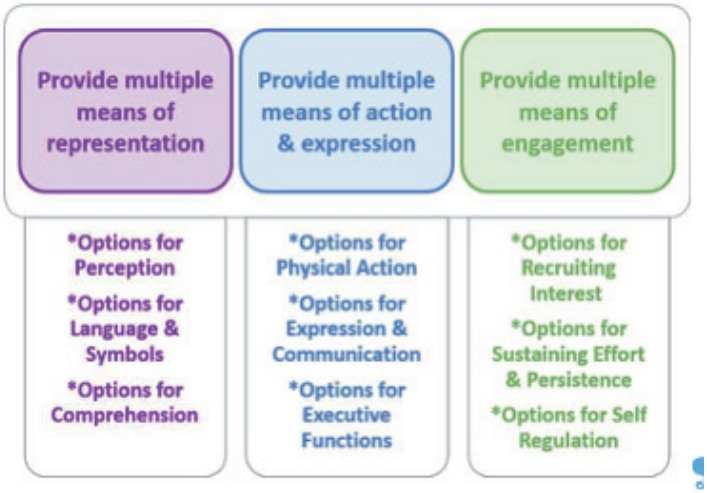

Figure 1. UDL Principles and Guidelines (CAST, 2018).

Technological accessibility and usability are vital for an information and knowledge society. Web accessibility refers to the possibility for all users, including those with functional diversity, to perceive, understand, navigate and interact with web contents, thanks to the fact that they follow design guidelines that allow access to people with a wide range of hearing, movement, visual and cognitive abilities (Abuaddous, Jali, & Basir, 2016).

Usability is a broader concept than accessibility; therefore, for a resource or page to be usable, it must be accessible in the first instance. However, despite the fact that accessibility, usability and integration of technologies are seen as reasonable practices, they are not always used in online courses (Edwards and Boyd, 2018). Assessing the accessibility of digital educational resources and online learning platforms is very important to ensure education for all, especially for students with disabilities (Alahmadi and Drew, 2017; Edwards, 2019).

Assistive Technologies – which for this case are technologies used to favor accessibility – designate/determine the systems and services related to programs for assistance, which allow people to lead a productive and independent life and be part of the social, labor and educational spheres (WHO, 2018). ATs enable access to educational information and content and to learning platforms themselves (Alahmadi and Drew, 2017).

Research, such as that undertaken by Wu (2015), Mironova, Amitan, Vendelin and Vilipõld (2016), Fidalgo and Thormann (2017) and Coleman and Berge (2018), shows that the accessibility needs, requirements and preferences of participants in virtual courses hosted on LMS platforms are diverse and that simplifying navigation is of great help (Rao, Edelen-Smith and Wailehua, 2015). In addition, Chatterjee, Juvale and Jaramillo (2017), Houston (2018) and Bray et al. (2023) describe the application of UDL principles in VLE, specifying that they offer alternatives for information presentation, interaction, expression and involvement with online learning and incorporating emerging technologies such as immersive education and simulators. Rogers-Shaw et al. (2018) and Ciasullo (2018) state that Inclusive Virtual Education is possible if it is designed with a methodology that involves knowing the students, developing accessible content, having a usable platform, and includes flexible didactics and evaluations that promote constant student motivation.

There are several standards and norms to consider in the design of a web page, which seek to make it more accessible. Yet although there are specific recommendations, this does not guarantee that web designers take them into account (Armano, Borsero, Capietto, Murru, Panzarea and Ruighi, 2018). To evaluate the accessibility of web content, two methods are used, one automatic and the other manual, which complement each other. The automatic analysis allows detecting accessibility problems through the use of tools, which are not infallible and have limitations, so it is necessary to perform a manual analysis with the participation of experts. The Moodle platform has been the subject of analysis in different distribution versions, regarding its accessibility (Moreno, Iglesias, Calvo and Delgado, 2011; Calvo, Iglesias and Moreno, 2014). Since then, the scope of measurement has been extended from accessibility to a broader concept such as usability.

In a usability test, the user is presented with the product and asked to use it intuitively or is asked what he/she thinks it can be used for (Krug, 2000). No single method should be used, but rather they are combined for best results. The Moodle platform has been evaluated using usability principles in several of its versions (Kakasevski, Mihajlov, Arsenovski and Chungurski, 2008) evaluated and compared the user experience when using different Moodle modules, giving recommendations for teachers and students that make it possible to improve authentication tasks, learning resources, assignments and communication. In 2013, Daneshmandnia carried out a usability evaluation on Moodle v.2.4. through expert inspection, revealing positive responses regarding the possibilities of this LMS. This result coincides with that found by Kipkurui, Wanyembi and Ikoha (2014), who identified that the learnability of the platform affects its usability. Orfanou, Tselios and Katsanos (2015) propose the use of the SUS scale (Brooke, 1996) to evaluate the perception of usability of Moodle platform users, finding that it is at a satisfactory level according to the students who participated.

METHOD

As can be seen in Figure 2, this study has been developed using a mixed design, which allows a series of systematic, empirical and critical processes that involve collecting qualitative and quantitative data. It was designed as a multi-method study adapted to our needs, contexts, circumstances and resources, in order to achieve a better understanding of the analyzed phenomenon (Hernandez-Sampieri, Fernandez-Collado and Baptista-Lucio, 2014; McKim, 2017).

The objective is to analyze the viability of Moodle v.2.x and v.3.x for applying the UDL, based on an evaluation of its accessibility and usability. The objective itself is framed within the design of the evaluation of an educational program. The responses of this evaluation may or may not directly judge the value of an object, which in this case corresponds to the usability of two Moodle platforms. One platform is at the University of Atlantico (UA) in Colombia, using version 3.3, and the other is at the University of Granada (UGR) in Spain, with version 2.7. Both platforms reflect the two production environments that the Moodle.org community makes available to centers and institutions, generally referred to as Moodle v.2.x and v.3.x.

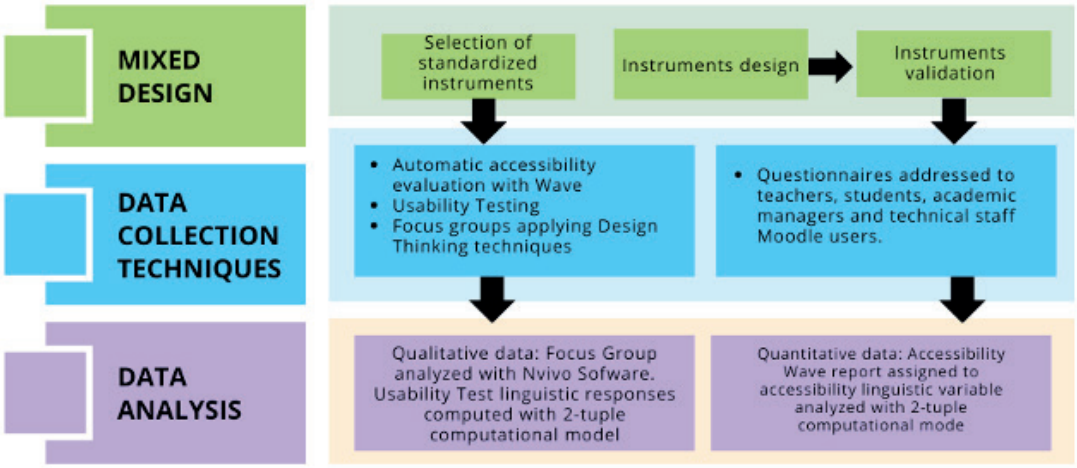

Figure 2. Design-based mixed research cycle

Participants

Given the mixed characteristics of the study, it was necessary to have different samples to collect the relevant qualitative and quantitative data. In particular, the users considered are all strata of the same universe, i.e., with experience in the use of the LMS Moodle platform, since these selections reflect different levels of interaction with the platform. Due to the instruments used, it was necessary to define different sampling techniques, also taking into account that one of the characteristics of mixed methods is the possibility of combining different sampling techniques that make it possible to solve the problem statement (McKim, 2017).

- First sample. This was composed of 9 people belonging to the coordinating and technical team of the Moodle platform in the two universities studied. All the participants work in the IT and e-learning areas, and most of them have between 6 and 20 years of experience.
- Second sample. This comprised a type of volunteer participant, i.e., individuals linked to undergraduate studies at the two institutions, who shared their experiences in the Usability Test (UT) of the Moodle platforms. There were 213 voluntary participants, 126 people from the University of Atlantico and 87 from the University of Granada.
- Third sample. This was formed by usability experts from both institutions – professionals in IT who are familiar with the platforms but who are not currently directly linked to the departments that administer them. There were 3 experts from the University of Atlantico and 4 from the University of Granada, for a total of 7 people.
- Fourth sample. This was made up of Moodle platform users in their role as student teachers or technical team members. A total of 22 people participated in these groups, which will be explained below.
- Fifth sample. This consisted of 531 participants on the MOOC course held at the University of Atlantico, who answered the second and fourth questionnaires to evaluate this educational program. Of this sample, 21 participants stated that they had some type of functional diversity; 50 had entered the educational system late; 30 had difficulties in mathematics; 6 had difficulties in reading and writing; 7 had attention deficit disorder with or without hyperactivity; and 1 had autism spectrum disorder.

Data Collection and Analysis

Considering the mixed design of the present study, different types of data collection instruments have been designed, which are presented in Table 1 and detailed below. Template files and also data from our case study are publicly available as a GitHub repository, at https://github.com/ari-dasci/OD-Moodle-Usability-Assessment

Table 1. List of instruments used in this research and type of data

Instrument	Type of data
An AT Matrix	Qualitative
Report from Wave accessibility evaluation tool	Quantitative
Usability Testing	Mixed
Focus groups	Qualitative
Seven questionnaires	Quantitative

Assistive Technology Matrix

The objective of our Assistive Technology (AT) matrix is to systematize in an organized way the evidence found on the search for free and online technology, susceptible to be used in the VLEs by teachers and students. Such AT are intended to improve the tasks of communication, reading, writing, mathematical exercises, accessibility and organization. The information collected in the matrix is qualitative and its results became an annex to one of the questionnaires addressed to the technical team that manages the Moodle platform. The 24 selected AT instances are classified into communication technologies, accessibility, reading, writing, mathematics and time organization.

Web Accessibility Evaluation

For the automatic evaluation of accessibility, the Wave tool was selected. The tool loads the web page, and detects and marks accessibility errors on it. When these errors are clicked upon, a detailed report is given, thus facilitating under- standing. For its interpretation, we used the Website Accessibility Conformance Evaluation Methodology (WCAG-EM) 1.0, a methodology that determines the accessibility level of a web page according to Web Content Accessibility Guidelines 2.0. This is a flexible support resource that does not define additional requirements, nor does it determine a specific tool for its application, and it allows self-evaluation and evaluation by third parties (W3C, sf). In the following GitHub resource, you can read our analysis for PRADO and SICVI 567 that encompasses both Wave accessibility reports.

Usability Testing

For the evaluation, the MOOC course title Inclusive educational contexts: design for all people was hosted on both LMS platforms, and the 12 review pages of the course were defined and organized according to the tasks to be used in the usability test.

Focus Group for Moodle Users

Focus groups, also called discussion groups, are sessions in which topics are discussed in depth. These consisted of meetings of people where meanings were constructed in a collaborative way, guided by a moderator. In this case, positive and negative aspects were discussed, as well as suggestions for improvement of the UA's Moodle platform. The focus group was structured by means of two techniques proposed by Design Thinking, the Journey Map and the Feedback-Capture-Grid. These techniques are methods that make it possible to analyze and discover people's needs, under the paradigm of universal design, and which therefore may help to improve the design of a MOOC course. We had the participation of 22 people from the UA, belonging to the fourth sample described above. More information is given in our report.

Questionnaires

In the search for a reliable, valid and objective process, three main stages were carried out: design, validation and piloting. These stages led to the final version of the questionnaires. The validation process of seven questionnaires was carried out using the online modified Delphi Method and with the participation of ten expert judges. All of them are professionals in the field of education and engineering with extensive experience in the field of virtual education and inclusive education. The experts' evaluations were analyzed quantitatively and qualitatively. The pertinent qualitative modifications were made, and in order to evaluate the internal consistency of the questionnaires, a pilot test was applied. We then carried out Cronbach's Alpha on its results. The Cronbach's Alpha index ranges from 0 (0%) to 1 (100%), where the minimum expected was 0.8 (80%), and it showed the degree of concordance of the questionnaire responses. The values obtained in the questionnaires were higher than 80%, thus demonstrating their internal consistency (Bujang, Omar and Baharum, 2018).

The total set of questionnaires is listed in Table 2, and their template can be downloaded at the GitHub repository. It is important to mention that a five-term Likert scale was used to answer the questionnaires: strongly agree, partially agree, indifferent, partially disagree, strongly disagree.

Table 2. Target audience and purpose of each questionnaire

Instrument	Purpose
Q1: Moodle Managers	To determine the opinion regarding the attention to diversity in the VLE and the integration of AT tools in Moodle and how these can favor its usability.
Q1: Technical administrators	Determine the opinion regarding the integration of AT tools to the Moodle platform and how these can favor its usability.
Q2: Moodle user teachers	To determine the opinion about the usability of the Moodle platform of users with experience in the teaching role.
Q2: Moodle user students	Determine the opinion about the usability of the Moodle Platform of users with a student role.
Q3: Usability experts	Determine the opinion regarding the usability of the Moodle Platform. Evaluate 10 usability dimensions or attributes: Web Accessibility, Identity, Navigation, Efficiency, Effectiveness, Help, Content, Easy to Remember, Satisfaction, and Resource Accessibility.
Q4: MOOC participants with experience in teaching	Determine the opinion regarding the application of UDL principles in their pedagogical practice in virtual learning environments.
Q4: MOOC Moodle participants	Determine the opinion regarding the MOOC course Inclusive Educational Contexts: Design for All, which was designed under the principles of UDL.

The instruments used in the research enabled a broad analysis of the usability of the Moodle platform and how the application of the UDL in VLE can meet the needs of users of this type of technological tool. It was important to discover the usability of the Moodle platform in its v.2.x and v.3.x versions from the perspective of users with teaching, student and administrative roles, as well as to carry out usability evaluations using automatic tools and taking into consideration the opinion of experts. In this study, the Wave automatic accessibility evaluation tool and the Q3 questionnaire were used to obtain an evaluation on accessibility and usability, respectively.

It was also important to learn the opinion of managers and technical staff who administer Moodle platforms about online AT tools that could be integrated into the LMS platform to improve learning conditions and promote education for all. The Q1 instrument was used to collect information from both groups of users. Furthermore, we needed to find out the opinion of the MOOC course participants, before and after, in order to learn about their experience on the Moodle platform and to determine if the MOOC, designed under the principles of the UDL, fully met its purposes and was adapted to the needs of the participants. All the instruments used shed light on the usability not only of the Moodle platform in two of its versions, but also the course that was hosted on it and designed under UDL principles, with an emphasis on the Q2 and Q4 questionnaires. The quantitative data were collected with the Wave accessibility assessment tool, the questionnaires and the UT, while the qualitative data were processed using NVivo 11.

Assessment under the Computing with Words Paradigm

Computing with Words (CW) is a methodology that uses human perceptions and opinions to reason and calculate instead of numerical measures. CW has the ability to optimize the approach experts use to calculate assessments of decision- making problems. To complement the use of CW, it is necessary to use linguistic variables. A linguistic assessment was carried out to provide an overall estimate of all the results obtained by applying the instruments, based on fuzzy set theory (Zadeh, 1965), which is widely used for the processing of qualitative data, based on the methodology of computing with words (Mendel, Zadeh, Trillas, Yager, Lawry, Hagras and Guadarrama, 2010). Thanks to this methodology, algorithms can be developed that operate with data expressed by means of linguistic variables, although this research focuses only on the assessment and not so much on their processing.

Fuzzy linguistic valuation makes it possible to represent qualitative aspects, based on linguistic variables, which do not have numerical values but words expressed in natural or artificial language (Zadeh, 1975). Each linguistic value is characterized by a label and a meaning, where the label is a word that belongs to a set of linguistic terms, and the meaning is what it refers to and can be interpreted depending on the context.

In this research we use a term set S of $n = 6$ that gives domain to the usability linguistic variable, with $S =$ *worst, poor, good, ver y good, excellent, unmatched.* . In this way $s_i \in S$, $i = (1, \ldots, n)$ is a valid output of the Brooke System Usability Scale (SUS) questionnaire (Brooke, 1996). A valid computational model which allows to operate with a linguistic variable is the 2-tuple fuzzy representation (Herrera & Martinez, 2000). For instance, *usability y* = s_2 (which is poor) is a better approximation of the computed SUS score in the range 0, 100. This questionnaire is simple, since it has an input of a 10-item scale that allows a global evaluation of usability. Linguistic rating is adopted in this study because it allows the comparison of platforms in terms of usability values expressed as human perceptions and opinions, which are more understandable than numerical measures.

FINDINGS

The results give an account of the analysis carried out from the application of the instruments. They allow us to recognize the perspectives of different users of the Moodle platform, as well as the results of the accessibility and usability tests.

Applicability of Assistive Technologies in Moodle

We created a TA matrix resource to collect 24 solutions that cover different potential needs for users. The purpose was to find online AT tools that could be made available to Moodle platform users, in order to

improve the Moodle platform configuration for usability. Among the AT tools selected are interpretation services in Spanish Sign Language and Colombian Sign Language, optical character recognition (OCR) tools, dictation tools, text to audio converters and vice versa, grammar checkers, dictionaries, and mathematical equation editors, among others.

The analysis of the results of the Q1 questionnaires showed that only one coordinator, corresponding to 20%, agreed that teachers requested support in the use of ATs to assist students with special educational needs. However, the lack of appropriate use of these tools by the coordinators of the virtual education services was evident. Fifty percent of the members of the technical team recommended the integration of six specific online ATs, such as the sign language interpretation service, the relay center, the RAE dictionary, Pomodoro, and the two online equation editors. Similarly, 75% agreed on recommending the Checklist for Moodle. All respondents stated that the incorporation of ATs into the Moodle platform favors inclusion and stated that they require training to learn how to use them.

Usability Assessment

Usability refers to the ease of use of the Moodle LMS platform. To be usable, it must be accessible in the first place, so it is pertinent to evaluate the accessibility of the v.2.x and v.3.x versions.

Accessibility Evaluation Results

Wave was used as an online service for web site accessibility evaluation and was applied to Moodle v.2.x and v.3.x instances. The tool was applied to the five groups of tasks and pages to which the user has access.

Table 3 synthesizes the metrics obtained for the v.2.x instance in terms of errors, alerts, features and accessibility according to tasks. The accessibility column indicates the global labels obtained according to the level of compliance with the standards proposed by the W3C. The usability column, added by us, allows us to provide a linguistic interpretation of usability according to all the results. This assessment is given by the researcher when reviewing the results of the automatic reports. For the case analyzed, it has a negative impact on usability, since it is not accessible to people with functional diversity, and is not very usable in general. It was observed that the pages with the highest number of errors are those related to grade tracking, edit profile and glossary activity, with 96, 74 and 72 errors respectively.

Table 3. Report by Wave in Moodle v.2.x

Task type	Task	Page	Errors	Alerts	Features	Accessibility	Usability
Platform Login	Moodle login	login-dialog	16	13	8	A	Poor
	Find Course	home-page	49	22	33	A	Poor
	Course access	course-page	46	121	156	A	Poor
Account settings	Change preferences	edit-profile	74	84	161	A	Poor
Course view	Content access	content-fetching	39	29	93	A	Poor
	Access to news	page-fetching	39	33	101	A	Poor
Communi-cations	Forum access	forum-main	39	31	94	A	Poor
	Send a message	messaging	56	43	116	A	Poor
	Chat participation	blogging	41	27	87	A	Poor
Activities	Task access	task-view	46	29	89	A	Poor
	Questionnaire access	questionnaire-view	7	29	97	A	Poor
	Glossary access	glossary-view	72	35	93	A	Poor
	Rating follow-up	rating-view	96	48	101	A	Poor
		Total	620	544	1229	A	

Table 4 shows the results of the Moodle v.3.x evaluation. It was observed that the pages where the highest number of errors, alerts and features were concentrated were the course home page with 103 incidents, profile editing in preferences with 71, and messaging with 49 errors reported. The errors detected by the tool indicated accessibility problems that need to be corrected, as they pose difficulties for the end user.

Table 4. Report by Wave in Moodle v.3.x

Task type	Task	Page	Errors	Alerts	Features	Accessibility	Usability
Platform Login	Moodle login	login-dialog	6	5	4	A	Poor
	Find Course	home-page	31	28	29	A	Poor
	Course access	course-page	103	83	121	A	Poor
Account settings	Change preferences	edit-profile	71	31	60	A	Poor
Course view	Content access	content-fetching	10	24	21	A	Poor
	Access to news	page-fetching	10	30	33	A	Poor
	Forum access	forum-main	9	23	19	A	Poor
Communi-cations	Send a message	messaging	49	32	51	A	Poor
	Chat participation	blogging	10	21	14	A	Poor
Activities	Task access	task-view	14	25	17	A	Poor
	Questionnaire access	questionnaire-view	7	18	13	A	Poor
	Glossary access	glossary-view	37	23	17	A	Poor
	Rating follow-up	rating-view	12	27	23	A	Poor
		Total	362	370	422	A	

Usability Testing

To carry out this evaluation, a course was organized in Moodle v.2.x and v.3.x platforms and 28 tasks were defined for this test. The success of the completion of each task was recorded (if achieved/not achieved), as well as the time in seconds used and the emotion generated in the participant when he/she faced that task. This value is given by the linguistic variable *emotion* = {*positive, neutral, negative*}. A total of 213 users with the role of students participated, of whom 15 reported having special educational needs such as hearing, visual or organic disabilities and late entry into the educational system.

Table 5 presents a summary of the tasks that participants successfully completed in both versions of the Moodle platform and the average time it took them to complete them expressed in seconds. The emotion column shows the most predominant and estimated average results for each task. Lastly, the column labeled usability has been graded based on the results obtained and using the fuzzy linguistic approach.

Table 5. Summary by Task Accomplishment at UGR and UA: Average Time of Duration (ATD) and the linguistic variable *emotion* = {negative (-), neutral (0), positive (+)}.

Task type	Task	Estimated	Success		ATD		Emotion		Usability	
			v2x	v3x	v2x	v3x	v2x	v3x	v2x	v3x
Platform Login	1. Moodle login	20-30 s	100%	100%	27 s	52 s	0	+	Unmatched	Unmatched
	2. Find Course	20-30 s	90%	100%	42 s	49 s	0	+	Unmatched	Unmatched
	3. Course access	10-20 s	100%	98%	7 s	4 s	0	+	Unmatched	Excellent
Technical Support	4. Locate FAQ	40-50 s	88%	55%	49 s	60 s	0	-	Unmatched	Poor
	5. Contact form	60-90 s	90%	25%	30 s	174 s	0	-	Unmatched	The worst
	6. Change language	60-90 s	93%	70%	21 s	104 s	0	+	Unmatched	Very good
Account settings	7. Set preferences	60-120 s	90%	90%	72 s	85 s	0	+	Unmatched	Excellent
	8. Upload image	60-120 s	84%	78%	100 s	39 s	0	+	Excellent	Very good

Content access	9. Access to news	20-60 s	77%	86%	63 s	142 s	0	+	Excellent	Excellent
	10. Download a file	40-80 s	98%	93%	29 s	80 s	0	+	Unmatched	Excellent
	11. Directory download	50-90 s	94%	78%	30 s	95 s	0	+	Unmatched	Very good
	12. Follow link	20-60 s	96%	77%	26 s	74 s	0	+	Unmatched	Very good
	13. Embedded video	20-60 s	96%	88%	25 s	48 s	0	+	Unmatched	Excellent
	14. Viewing a page	40-80 s	92%	90%	34 s	66 s	0	+	Unmatched	Excellent
	15. Page Reading	40-80 s	92%	87%	38 s	81 s	0	0	Unmatched	Excellent
	16. Page Displaying	40-80 s	92%	85%	37 s	72 s	0	+	Unmatched	Excellent
Communi-cations	17. Send a message	50-90 s	92%	81%	41 s	116 s	0	+	Unmatched	Very good
	18. Chat participation	60-120 s	73%	79%	73 s	107 s	0	0	Very good	Very good
	19. Submit assignment	60-120 s	98%	76%	54 s	129 s	0	+	Unmatched	Very good
	20. Answer questionnaire	60-120 s	100%	87%	50 s	116 s	0	+	Unmatched	Excellent
Activities	21. Add to glossary	60-120 s	99%	78%	120 s	150 s	0	+	Unmatched	Very good
	22. Set up groups	60-120 s	94%	11%	57 s	108 s	0	-	Unmatched	The worst
	23. Adding to forum	90-120 s	87%	80%	93 s	110 s	0	+	Excellent	Excellent
	24. Formatting text	60-120 s	79%	81%	97 s	85 s	0	+	Excellent	Excellent
	25. Creating a link	60-120 s	91%	69%	77 s	99 s	0	+	Unmatched	Very Good
	26. Insert an image	60-120 s	92%	80%	61 s	79 s	0	+	Unmatched	Excellent
	27. Resize the editor	40-80 s	72%	35%	59 s	89 s	0	-	Very good	Poor
	28. Rating follow-up	60-90 s	92%	89%	34 s	73 s	0	+	Unmatched	Excellent

The block of tasks performed by between 100% and 90% are those related to the start of the platform. It should be highlighted that the student users of v.2.x mostly rated the completion of the tasks neutrally, while the users of v.3.x gave the positive rating to a greater extent to describe the emotion. The tasks of accessing the form with the platform's technical support and forming groups show significant differences between the users of the evaluated versions. We observed that the v.2.x users performed them more easily than the v.3.x users.

Questionnaires Q2 and Q3

With respect to the results of the Q2 questionnaires, addressed to teachers and student users of the platform, it was noted that both were in complete agreement that learning to use the platform and its new functions is simple. They also felt that they can explore the functionalities of the platform by trial and error. The sections of the platform were easily identified, expressing that they strongly (71% and 53%) and partially agree (41%), respectively. Similarly, 46% of the respondents (55 people) and 37% (72 students) stated that the Moodle platform is similar to other common interfaces for teachers. Both types of users expressed that the platform is easy to use, even after not having used it, and they strongly agree (62% and 55%). A total of 77 teachers, representing 65%, totally agreed that the functioning of Moodle is satisfactory, as did 117 students, corresponding to 60%. Likewise, 93 teachers (78%) and 129 students (66%) stated that they would recommend the Moodle platform to people who might require an LMS system. It was observed that both teachers and students thought that the Moodle platform has an attractive interface (60% and 46%), its organization is clear (70% and 52%) and logical (65% and 51%) and that the environment is user-friendly (73% and 60%). The above shows a positive assessment of Moodle's usability.

The Q3 questionnaire aimed at usability experts was answered by engineers linked to the University of Atlantico and the University of Granada, but who are not responsible for the administration of Moodle platforms. The results showed that, according to the experts, both v.2.x and v.3.x had an adequate contrast between background and text, as well as a typography that facilitates reading. However, differences were observed between these platforms in terms of alternative text. The group of experts who evaluated the v.2.x. instance reported that they were indifferent to the use of the alternative text, while two experts from the v.3.x. evaluation group, representing 67%, expressed a positive evaluation, and finally one expert (representing the remaining 33%) expressed a negative evaluation. Regarding the hierarchical organization of the information, the v.2.x group stated that their opinion was indifferent, whereas for the v.3.x group, three experts (75%) totally agreed that there is easy access to the information and partially agreed (50%) that actions can be easily canceled.

The opinion of the expert group for v.3.x was partially in agreement on the question of whether the platform complies with navigability features. Opinions were more disparate with respect to the action cancellation feature. Sixty-seven percent (two experts) partially agreed that the help section is easy to locate, while each of the respondents expressed varying opinions about the help manual and contacting technical support. With respect to v.2.x, fifty percent (two experts) expressed that finding help is easy, seventy-five percent (three experts) expressed indifference to the manuals, and this same percentage expressed partial agreement that they have means of contacting the technical support team. Regarding the headers, it was observed that both v.2.x and v.3.x are clear and descriptive according to the experts, who were in full and partial agreement, respectively. A pop-up window is an element that appears on the screen, in this case, when accessing a section of the platform, and on this aspect, the v.2.x and v.3.x experts were in full agreement that the use of these is discreet.

Regarding the use of the highlighted sections, the majority of respondents in v.2.x were indifferent about this element of usability. For the v.3.x case, they strongly agreed. The evaluators stated that both v.2.x and v.3.x are pleasant and satisfactory to use, with data in the strongly agreed column, as shown in Table 5, and partially agree on the attractiveness of the v.3.x platform by 67% (two experts). The Q3 questionnaire directed at experts was applied to evaluate the usability of both Moodle platforms. The results obtained in both indicated good usability, considering the linguistic evaluation given.

Qualitative Data Analyzed with NVivo

In order to analyze the records obtained in the focus groups and the UT, as well as the presence of important elements, three categories of analysis identified through the use of NVivo software were chosen. The categories chosen by the researcher are the positive aspects, negative aspects and suggestions for improvement in the blocks of tasks faced by the users, as well as general comments on the Moodle platform. The most highly valued tasks (with a total of 12 references) are those related to the use of Activity resources. Users did not express comments or make positive references regarding the tasks of accessing technical support and user account management in either of the two sources analyzed. Likewise, no positive aspects were referenced in the UT regarding user account management, access to information and resources/content and general comments on the platform.

Analysis based on Computing with Words Methodology

The linguistic variable usability allows us to represent the global view of the usability property, and we applied it to both platforms. It refers to an interpretation of the global results of the instruments that arises from the point of view of the research team. Table 6 shows the usability of both platforms in comparison.

The conclusion reached is that the usability of the v.3.x platform was good, as was that of the v.2.x platform. However, these platforms require adjustments in their configuration to be made more accessible, and an intervention by the technical team that administers them, since the rating of poor was obtained by both. Likewise, a thorough review by the technical team is required to comply with accessibility standards. It should be made clear that questionnaires Q2 and Q4 were applied in the MOOC course developed only on the v.3.x platform; therefore, there is no data for v.2.x.

Table 6. Linguistic usability evaluation of Moodle v.2.x and v.3.x.

Instrument	Moodle v.2.x	Moodle v.3.x
Wave accessibility evaluation	Poor	Poor
Usability Testing	Good	Good
Emotions in Usability Testing	Positive	Positive
Q2 Moodle user teachers and students	-	Very good
Q3: Usability experts	Good	Good
Q4: MOOC participants with and without experience in teaching	-	Very good

MOOC Course Evaluation

The educational program proposed in this research is the MOOC Inclusive Educational Contexts: Design for All (MOOC-IEC). This course was designed based on the parameters of the UDL. The following are the results obtained at the end of the course, which reflect the opinion of the participants. First, the opinion of the participants with teaching experience in LMS platforms is shown, followed by the opinion of the participants on the design and experience after completing the course. Table 7 presents the results of the Q4 questionnaire in its two versions, one addressed to MOOC participants and the other addressed to participants with teaching experience in virtual educational environments. The first two columns of the table present the principles and guidelines of the UDL, followed by the Likert scale of the questionnaire.

The results of the Q4 questionnaire show that participants with and without teaching experience expressed full agreement that the three UDL principles were accounted for, especially the options of effort and persistence and self-regulation, with values above 80%. Regarding the fuzzy linguistic assessment of usability, the data showed a very good usability. In general, all rating results were concentrated on the Strongly Agree and Partially Agree scale values, both for participants with and without teaching experience.

Table 7. Questionnaire results according to UDL principles. Scale: Strongly disagree, partially disagree, Indifferent, partially agree, strongly agree. Other acronyms: participant (P), participant with teaching experience (PTE)

UDL principle	Guideline	SA		PA		I		PD		SD	
		PTE	P	PTE	P	PTE	P	PTE	P	PTE	P
I	Perception	65%	67%	24%	19%	6%	10%	2%	1%	3%	3%
	Language and symbols	79%	60%	11%	17%	5%	20%	3%	2%	2%	1%
	Comprehension	79%	87%	18%	12%	1%	1%	2%	0%	0%	0%
II	Physical performance	73%	80%	20%	18%	3%	2%	4%	0%	0%	0%
	Execution	79%	74%	18%	23%	1%	2%	1%	1%	1%	0%
III	Pursuit of interests	75%	70%	21%	27%	1%	1%	3%	2%	0%	0%
	Effort and persistence	87%	84%	9%	15%	2%	1%	1%	0%	2%	0%
	Self-regulation	84%	79%	14%	15%	1%	6%	1%	0%	0%	0%

DISCUSSIONS AND CONCLUSION

The VLE organizes didactic resources that focus on students by analyzing their characteristics and learning styles. The VLE favors autonomy and self-regulation, through the use of and access to the different resources available. VLEs are a necessity in all educational institutions and their accessibility is of the utmost importance for students, including those with disabilities (Alahmadi and Drew, 2017; Kent et al., 2018; Crisol, et al., 2019; Edwards, 2019; Vilaverde, 2020).

One of the objectives of the study was to identify online Assistive Technologies (ATs) that can be integrated into Moodle in order to improve its usability. In this regard, we found that there are options that initially enhance accessibility. ATs facilitate both accessibility and the completion of tasks faced by users of virtual platforms, because they allow the use and manipulation of different formats that guarantee access to information and knowledge (Alahmadi and Drew, 2017). There were different AT options according to their function, ranging from screen magnifiers, optical character recognition, text-to-audio converter and screen readers for people with visual functional diversity, task organizers for people with autism spectrum disorder, audio-to-text converter for people with motor functional diversity, and voice recorders for those with reading and writing difficulties. One of the great contributions of the online ATs selected in this study is their open and free use, since no investment is required by users to access them, and they thus become empowered with their use. Promoting accessibility in VLEs is necessary to ensure that all social groups have access to virtual education and is supported by a legal framework that is becoming increasingly important worldwide every day (Alahmadi and Drew, 2017; Edwards and Boyd, 2018; Edwards, 2019).

The members of the virtual education departments, both academic and technical managers, indicated that students with special educational needs participate in virtual classrooms. They also recognize a potential in TA tools for promoting inclusive education. However, they lacked mastery of them and were reserved when suggesting their integration in Moodle.

Our study recognizes accessibility as an important component of usability. No web page can be usable if it is not first accessible to users. Therefore, web accessibility and usability metrics were selected to be applied in the Moodle platform, using user-centered design techniques, and a theoretical review on usability and accessibility, and their application to the VLE, was undertaken. For accessibility, an automatic evaluation was completed using the free Wave Tool. This tool reviews and identifies accessibility difficulties that may occur on a web page.

Both the v.2.x platform of the UGR and v.3.x of the UA mostly obtained results of single A labels, so the platform requires improvements to meet the diversity of its users and improve accessibility conditions according to the standards proposed by the W3C. Both platforms were linguistically evaluated with the adjective poor, given the conditions they present and accessibility barriers for users with functional diversity.

As a complement to the selected usability metrics, in this research we applied a Usability Testing (UT) approach as a key method of inquiry into the Moodle platforms in the study. Subjecting users to tasks that are carried out in Moodle, verifying whether they complete them, how long they do it and the emotions they feel when facing them, gave the opportunity to analyze the degree of usability of these systems. The evaluation was not limited to the verification of accessibility standards, because although these are both important and a legal requirement, it is essential to determine the factor of human interaction with the Moodle platform. Hence the relevance of the usability results, which in this case and according to the selected metrics, found that in the UT users took more time than estimated to complete the tasks of accessing the technical support form, updating the profile image and adding an entry to the glossary. Likewise, the tasks they had more difficulties completing were those of forming groups, expanding the editor's area and accessing the technical support form, leaving them with negative emotions.

With respect to the opinions of users of the Moodle platforms in the study, it is evident that although the experts state that the platforms meet the attributes of good usability, as expressed in the Q3 questionnaire, and that teachers and students who responded to Q2 reaffirm this by indicating that it is easy to learn to use, efficient, easy to remember, error tolerant, produces satisfaction and is attractive, there are suggestions for improvement made by users in the focus groups.

The positive aspects are directly related to the activities that users can do on the course, while the negative aspects mainly concern the tasks associated with the start of the platform and access to content. Likewise, they also suggest improvements in the access to resources and contents. Overall, this allowed the researcher to give a linguistic valuation based on the adjectives proposed by the System Usability Scale, resulting in usability = poor for v.2.x, and usability = good for v.3.x.

Finally, a MOOC type educational program was designed, which presented an introductory module and the content organized into 3 modules, 42 educational resources in different complementary formats (audio, text, video) and 12 evaluation activities (6 mandatory and 6 optional). This was used as a context for data collection to discover the opinions of the participants with and without teaching experience, on the application of the UDL in the VLE. The products, which have been designed under the principles of equality, flexibility, simplicity and intuition, seek an environment in which everyone can participate, recognizing equal opportunities, respect for the rights of all and the participation of all students (CAST, 2018).

Participants rated the pilot experience positively, indicating, according to the answers obtained in the Q4 questionnaire addressed to participants, that the guide- lines proposed by the UDL paradigm were satisfactorily met. Through the course design, platform configuration and content creation, multiple means of representation, forms of action and expression and forms of involvement with learning were provided.

The design of this online training action brings benefits in quality inclusive virtual education, it improves accessibility, without the need for technical adjustments in the platform, and involves the participants in their learning. VLEs designed using the principles set forth in the UDL do not imply that the teacher develops a unique path for each student and their needs, but that the variability of this system is taken into account through the prediction of the possible ways in which students can learn in a flexible way (Dickinson Gronseth, 2020; Frumos, 2020; Griful-Freixenet, et al., 2020).

This educational initiative is a successful complement to the academic experience provided by students, graduates, officials, teachers and external guests and contributes to the democratization of education. It was a space for continuous learning, where participants shared and discussed different opinions and experiences of what Design for All entails in inclusive educational contexts. The statistics of the course show that a total of

520 people accessed the platform at least once and completed the activities that allowed 215 participants to be certified, corresponding to 27% of the population. Offering learning paths adapted to the characteristics of the participants and maintaining adequate feedback in MOOC courses can reduce dropout rates (Borrella, Caballero-Caballero and Ponce-Cueto, 2022)

The fulfillment of the specific objectives made it possible to carry out the general objective of the study, which consisted of designing a methodology to evaluate the usability of the Moodle platform based on the principles of UDL. This methodology is transferable to other contexts and institutions that wish to consider virtual education for all. UDL applied to a VLE promotes learning opportunities, improving pedagogical practices for a great diversity of students, including those with and without functional diversity. This enhances student retention in online courses, thus tackling one of its great challenges, the high dropout rate.

Virtual Learning Environments have evolved over the years, and today web designers, content creators, and teachers are concerned about usability as a present feature, since, if they focus on the student as the protagonist in education, they must recognize the wide variety of learning styles and preferences for receiving information that they may have.

It is important to offer virtual education for all, recognizing the diversity of students, according to their physical, psychological and social characteristics, as well as their previous experiences and interests. This is a challenge because it involves the consideration of technological and pedagogical aspects that guarantee quality and educational equity in learning environments mediated by technologies that are constantly evolving and are widely used by a diversity of users.

The proposal that VLEs should consider the accessibility of platforms and digital educational resources favors inclusion processes. The Universal Design for Learning (UDL) can be applied to virtual educational contexts, more specifically to training actions on the Moodle platform, since it makes content more flexible so that everyone can access information and learning more easily.

The use of Assistive Technologies (AT) is a good option to improve accessibility to the information society and therefore to knowledge. These technologies allow access to the curriculum, activities, resources and communication for students with functional diversity. The design of VLEs for all should not be limited to the use of AT, but should incorporate pedagogical and instructional practices for students with and without disabilities, based on the principles of the UDL. ATs can be used by students with and without disabilities and support UDL.

It is important to mention that the staff in charge of supporting virtual teaching, both academics and technicians, indicate that students with special needs participate in virtual classrooms and recognize that these tools have the potential to enhance inclusive education. However, the diversity and disparity of techno- logical solutions does not encourage a deep mastery of them, which is why they show reservations when suggesting their integration into Moodle. Therefore, it is essential that the technical/managerial and pedagogical teams of support centers constantly monitor and update new ATs for virtual education in universities, provided that they wish to provide an inclusive service.

Limitations and Future Research Directions

This study has been limited to the community of Universidad del Atlantico in Colombia and Universidad de Granada in Spain. This restricts the scope of the results, also considering the versions of Moodle that both institutions had during the period of time in which the research was developed, however, the results of these contributed to the current versions. The development of the technical capabilities of the platforms and therefore the user experience through them was improved. It is expected to be able to carry out comparative studies of the applicability between different versions of Moodle also leading to an update with respect to the new version of the UDL presented by CAST in 2024. Similarly, it would be interesting to develop longitudinal studies based on current versions of the Moodle LMS platform.

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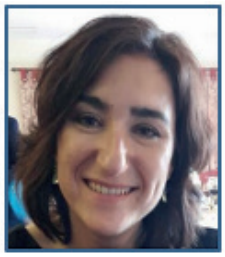

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