Improving Accessibility in Online Education: Comparative Analysis of Attitudes of Blind and Deaf Students Toward an Adapted Learning Platform

CONCEPCIÓN BATANERO-OCHAÍTA[1], **LUIS DE-MARCOS**[2], **LUIS FELIPE RIVERA**[3], **JAANA HOLVIKIVI**[4], **JOSÉ RAMÓN HILERA**[2], **AND SALVADOR OTÓN TORTOSA**[2]

[1]Computer Engineering Department, Polytechnic School, University of Alcalá, 28871 Alcalá de Henares, Spain
[2]Computer Science Department, Polytechnic School, University of Alcalá, 28871 Alcalá de Henares, Spain
[3]Department of Economics, Faculty of Economics, Business and Tourism, University of Alcalá, 28802 Alcalá de Henares, Spain
[4]School of ICT, Helsinki Metropolia University of Applied Sciences, 00079 Metropolia, Finland

Corresponding author: Concepción Batanero-Ochaíta (concha.batanero@uah.es)

ABSTRACT People with different capacities, such as the deaf and blind, have problems accessing educational content due to lack of accessible technology. Accessibility and usability are closely related concepts that share the goals for a satisfactory user experience. Existing literature establishes a direct relation between accessibility and usability, and reports that there are problems with both in learning platforms, and more generally with most websites. The objective of this paper is to evaluate the accessibility and usability of a learning platform by interrogating its participants. Three groups of students with different capacities (blind, deaf and deaf-blind) used an accessible learning platform prototype to assess the accessibility and usability of the platform and its contents. This article presents a comparative study of the perception and attitude of blind and deaf students towards the use of a learning platform adapted to their personal needs. Results showed that their attitude to the adaptation was very positive but there were differences in the perception of the ease of use of the application and with the level of difficulty to access the learning content. This work contributes to the body of knowledge by showing the effects that adaptations have on learning contents for blind and deaf students in terms of accessibility and ease of use through the analysis of the perceptions of participants. Future work may consider increasing the sample of students, as well as developing and testing new technologies and approaches that address other forms of functional diversity.

INDEX TERMS Accessibility, accessible content, attitudinal test, blind, deaf, educational technology, learning platforms.

I. INTRODUCTION

We consider the following definition of e-learning introduced by Young *et al.* [1] in 2012, which is based on the opinion of experts from around the world:

> E-learning is an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training,

The associate editor coordinating the review of this manuscript and approving it for publication was Rebecca Strachan.

communication, and interaction and that facilitates the adoption of new ways of understanding and developing learning. (p. 152)

This definition establishes a direct relationship between e-learning and new technologies, which reinforces the idea of an online Learning Platform (LP) as a conducive environment for improving accessibility in education [2] through advantages such as access to information from a distance and the ease of converting data to different types of formats (visual, textual or auditory) [3]. Dahlstrom-Hakki *et al.* [4] suggest that online learning can improve learning outcomes of people

with different capacities because it allows personalization for their individual needs. All these kinds of features can be integrated into LPs adapted to the personal needs and preferences of the students (PNP) [5] that allow users to enter their accessibility profiles and teachers to upload materials adapted to each learning object. When a student selects a learning object, the platform will show it in the format appropriate to their accessibility profile [6]. International standardization organizations work to define technical requirements necessary for the successful adaptation of LPs as well as update them continuously following the evolution of technology.

Accessibility in e-learning presents an increasingly expanding value [7], [8] due to its intrinsic relationship with new technologies as mentioned above. This requires resources, research, and development that facilitate a higher level of accessibility, as described by a study of e-learning environments websites in eleven Middle East countries [9]. Some LPs are adapted to different capacities [10] following different versions of the standards. However, the adaptation is not always successful for people with different physical capacities [11] that have to struggle with a lack of technology [12] compared to people with different vision and hearing capacities. In this context, different specific applications exist, mostly offering alternatives to the use of the mouse [13], [14]. One particular Moodle LP has been adapted through the mutual interaction of a scanner and large push buttons, although its current version is not supported by standards.

Regarding the concept of accessibility, which does not have a precise definition in this context [15], there are many works pointing to the connection between the terms accessibility and usability [2], [15]–[19]. Different definitions of usability highlight concepts like user experience, interaction or context of use [20]. The Web Accessibility Initiative, WAI [21] establishes the differences as well as the possible advantages of addressing both. In terms of the differences, it points out that accessibility only affects people with disabilities while usability affects all users, and that accessibility addresses the technical requirements of the code of applications while usability has a broader context of application. In terms of the advantages of combining them, WAI states both that accessibility can benefit from usability as the latter focuses on the interaction with the user, while many accessibility requirements also impact usability. In both cases, it is important that practitioners comply with recommendations set by standards. Burgstahler *et al.* [2] outline that usability can help to improve accessibility using technology. Iwarsson and Ståhl [16] describe accessibility as the integration of a personal and an environmental component, and therefore, suggest that accessibility should be replaced, in part, by the more complex term of usability, since it introduces an activity component. In the opinion of Petrie and Kheir [15], the definition of accessibility proposed by the World Wide Web consortium [22], could be called a "usability for people with disability" or a "usable accessibility" (p.1). The latter term is also used by Di Blas *et al.* [17]. Waddell *et al.* [23] describe accessibility as a subset of usability and comment that there

exists a more complex relationship between both by affirming that usability problems affect all users equally, while accessibility problems make access to the information difficult only for people with different capacities, and therefore put them at a disadvantage. Shneiderman [18] reports on "universal usability" (pp. 1, 2, 6) as a term including both usability and accessibility. Leporini and Paternò[19] suggest that accessibility and usability are two intertwined aspects that must be integrated appropriately so that access to information by people with different capacities is not threatened.

Our objective is to compare the opinions of two groups of students (blind and deaf) about an adaptation of Moodle LP to the students' Personal Needs and Preferences (PNPs) by considering accessibility and usability aspects. This paper is structured in 5 sections: Section 2 describes the state of the art, standardization, related projects, and presents the foundations for this study, section 3 describes the adapted LP and how to use it, and section 4 presents the methodology. We present results in section 5, and discussion and conclusions follow in section 6.

II. BACKGROUND

Accessibility in education has made considerable progress in the last decade. Various studies took into account diverse techniques for improving access to education for students with different abilities such as people with vision problems using haptic feedback technology [24], or using the Listening-to-Complexity system that provides synchronous auditory streams [25], or deaf people using a specialized designed sound lab [26]. Research from different perspectives about e-learning includes the study by Zafra *et al.* [27] on the effectiveness of e-learning, and by Kiget *et al.* [28] who evaluated the usability of e-learning systems at various universities. The use of MOOCs (Massive Open Online Course) and online courses is also increasing [29], [30]. They aim at consolidating e-learning as a key piece in future education, at the same time providing support to people with different capacities, although many authors acknowledged difficulties in this respect [31].

Besides previously mentioned research on educational websites, several studies have addressed accessibility in education. Freire *et al.* [32], and Lewthwaite and Sloan [33] introduced accessibility in engineering studies; Seale *et al.* [34] and Dowrick *et al.* [35] demonstrated that in UK and USA respectively, students with different capacities had difficulties with technical environments in higher education; the accessibility of different LPs has been analyzed including Blackboard [36] or Moodle [37], or compared like in the study of the accessibility between open source (Moodle) and proprietary (Sakai) LPs [38]; a study of 399 universities analyzed the relationship between web content quality and web accessibility in 16 countries [39]. The study concluded that Anglo-Saxon countries pay more attention to web accessibility, while Germanic countries pay more attention to web content. However, in Latin countries there is a positive relationship between both factors. So, universities that pay more

attention to web accessibility, also pay attention to the quality of web content; Acosta *et al.* [40] proposed a methodology for assessing the accessibility of online content publishers, taking into account the guidelines developed by international initiatives regarding accessibility; Brajnik *et al.* [41] used the Barrier Walkthrough method to demonstrate that user expertise affects the outcome when assessing web accessibility. Besides, Arrue *et al.* [42] presented a tool to assist researchers in designing remote experiments and analyzing results. Nacheva-Skopalik and Green [7] described an open-source toolkit for assessing the level of understanding and skills of students regardless of their different capacities. Campoverde-Molina *et al.* [43] introduced a systematic review to analyze the empirical methods of evaluating accessibility of educational websites concluding that they did not meet any version of the guidelines advised by standards [44]. International organizations for standardization and accessibility associations are then playing an important role in developing technical specifications to build accessible LPs.

Diverse publicly funded research projects have applied international standards. Many initiatives and organizations have emerged with the aim of collaborating in the improvement of accessibility in education. For instance, the G3ict (Global Initiative for Inclusive Information and Communication Technologies) initiative [45] was created by the United Nation Global Alliance for ICT and Development in cooperation with the Convention on the Rights of Persons with Disabilities (CRPD) [46]. G3ict promotes the digital accessibility and assistive technologies for learning and other areas. Another examples are the European Agency for Special Needs and Inclusive Education organization [47] that collaborates in the field of special needs in education, and the initiative of the U.S. Department of Education [48] assisting educational centers (as schools, colleges, universities, etc.) to build accessible websites and programs for people with different capacities. Currently, government institutions have launched new research projects to facilitate the development of accessibility. The following examples give an idea of the direction followed in this field.

- ECOMODE project (2015-2018) [49] lasted 4 years and developed innovative technology to allow the use of mobile communication devices for blind and elderly people.
- Easy Reading project (2018-2020) [50] built a software application that facilitates the reading of websites to people with different cognitive capacities by accommodating the structure and design of the websites and explaining the web content with symbols, videos, or images.
- InLife project (2016-2018) [51] developed a platform to transform daily activities in educative games using intelligent sensors and rewarding users for their actions or behavior, depending on the educational goal.
- WAI-guide project (2019-2021) [52] objective was the elaboration of open curricula on web accessibility

stressing on quality programs and scalable accessibility training.
- WADcher project (2018-2020) [53] built a platform and a set of tools to help with accessibility assessment, monitoring, and reporting. Moreover, it supports the creation of accessible websites and applications. The project also includes observatory tools for monitoring accessibility in the long term.

In addition to these projects, we wish to highlight research literature referring to the adaptation of virtual learning environments. Mirri *et al.* [10] adapted the aTutor platform following the IMS Access for All v1.0 [54] and ISO/IEC 24751 [55] standards. Laabidi *et al.* [56] proposed the adaptation of the Moodle platform according to the IMS Access For All v2.0 specification [57]. Both works showed how different forms had to be filled out by students and teachers. In a user experience study Rodriguez-Ascaso *et al.* [58] reported different problems when learners with different capacities handled accessibility profiles and learning objects adapted according to ISO/IEC 24751-1-2 standard. Another study [59] presented an adaptation of the Moodle learning platform according to IMS Access For All v3.0 specification [60] reporting the forms used and a list that included the adaptations, like audio description, detected for a student with vision problems.

Furthermore, complementary research has been conducted on accessibility in e-learning. One example is the Moodle platform-based t-learning system for people with different capacities that connects TV with Internet [61]. Another significant development was the DIAS tool [62] that simulates visual, auditory, physical and cognitive impairment. This application facilitated experimentation and testing in environments for users with different capacities, increasing developers' awareness of possible deficiencies so that they could create more efficient accessibility systems. Acosta *et al.* [63] proposed novel techniques to guide authors, designers, programmers, and testers in the publication of accessible and inclusive multimedia on the web. Raptis and Kakoulidis presented a tool [64] that improved the accessibility for blind students by means of converting online educational content into highly intelligible, near-natural synthetic speech. The EduRank algorithm [65] personalized educational content by combining a collaborative filtering system with a social voting method using a preference classification. The tool Torino [66] was useful for teaching computational thinking to children with different visual capacities.

The practical conclusion of this review of the current situation is that accessibility in educational systems is still underdeveloped. Reported evidence suggests that besides access to platforms and contents, it is necessary to provide a satisfactory learning experience to students with different capacities. The most significant problem reported is the lack of accessibility resources for the wide range of functional variety in people that needs to be addressed. Particularly, there is a lack of technical information on how to develop an accessible learning platform for different physical capacities.

ADAPTED LEARNING MANAGEMENT SYSTEM
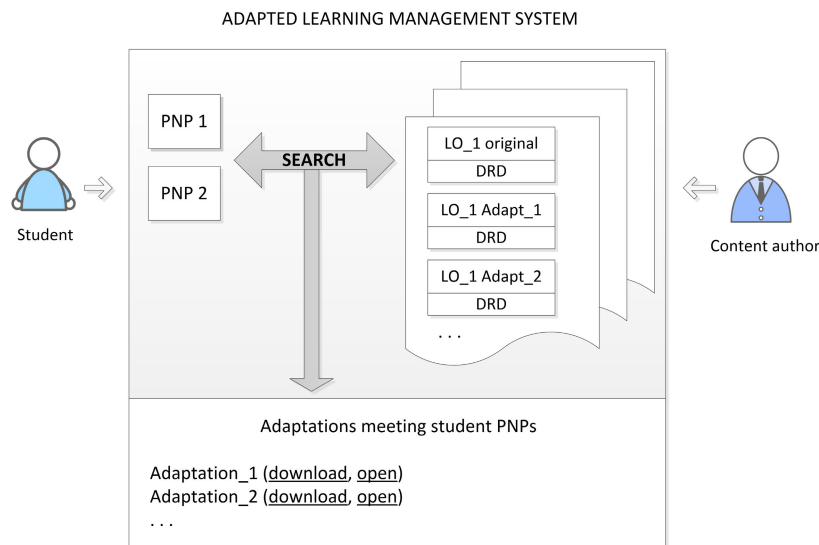
FIGURE 1. Procedure and actors involved in adaptation process.

Another concern comes from the dispersed nature of the available information. It is therefore impossible to address all functional diversity issues in a single approach. Furthermore, some types of functional diversity are less well-known or studied. Regarding different cognitive capacities, a distinct and novel methodology would be required to assess the adapted learning platform, while for deaf and blind students, it is only required to adapt contents and the learning platform. Given these difficulties, we chose to create an application that provided educational support through e-learning for people with visual or hearing functional diversity, or both. The adapted platform was designed in compliance with the latest version of the current standards presenting a simple architecture to facilitate the inclusion of other types of different capacities if needed just by adding new accessibility metadata descriptors. This study contributes to the literature by empirically comparing the opinion of two groups of students (blind and deaf) about the effectiveness and usability of the platform. This research is motivated by lack of evidence on the impact of adaptations based on the opinion of participants. This study stresses the necessity to assess and improve accessibility in education by exploring the perceptions of visually- and hearing-impaired learners when using the adapted learning platform model as recommended by existing standards and recommendations. We do not know of similar studies in accessibility in education. Existing studies focus on the design and implementation of platforms and contents. However, results that report testing with real users and compare their opinions and experiences are scarce [67].

III. ADAPTED LEARNING PLATFORM

An accessible learning object (LO) is composed of the original LO, its adaptations and the accessibility metadata of both the original LO andits adaptations. One example of an original LO could be a video, which includes visual and auditory access, while examples of its possible adaptations would be an audio description of the images (for blind people), subtitles (for deaf people), or a lengthy description of the images for conversion into audio by a screen reader (for deaf-blind people), etc.

The process for using an adapted LO involves the following steps. Teachers must upload the accessible LOs to the adapted platform. Students must create their PNPs when registering. PNPs describe the sensorial access mode, preferred language, or possible health risks of the LOs. Students get the adaptations that meet their PNPs when they click on a resource since the adapted LP prototype runs then a previous search returning the compatible adaptations. Fig. 1 shows the procedure.

The procedure to adapt the LP consists of three stages [59], which correspond to the three previous steps performed by the actors involved in the learning process. The following subsections describe each stage.

A. DIGITAL RESOURCES DESCRIPTION (DRD)

The teacher or content author must upload the original LO and its adaptations to the adapted platform, together with their accessibility metadata. Our prototype offers all the functionality needed to upload the adapted LOs. It initially requests the following three metadata: type and language of the adaptation, and hazard for health. It aims to make the process easy for content authors who may not be familiar with the standard. The remaining metadata are automatically filled in by the prototype based on an internal table. Each metadata item has its own set of possible values. For example, "adaptation type" can take one or several of the following values: "alternative text", "audio description", "captions", "e-book", "haptic", "high contrast", "long description", "sign language" and "transcript". Furthermore, the name of

Advanced user preferences and personal needs

Navigation   −|▯▯

Home

  ▫ My home

     Site pages

     My profile

     My courses

  ▫ My AFA PNP profiles

Settings   −|▯▯

     My profile settings

Profile name | PNP_DEAF

Select the access modes you feel comfortable with: | auditory / textual / visual

Select any type of adaptation you like over the access modes selected | alternativeText / audioDescription / captions / e-book

Select every language you could understand on a learning object: | Chinese / English / French / Spanish

Select all the hazards you need to avoid: | flashing / motionSimulation / olfactoryHazard / sound

(Save changes) (Cancel)

FIGURE 2. PNPs selected by a deaf student.

each metadatum clearly expresses its functionality. For example, "hazard" indicates the possibility that a LO component could impact negatively on student's health (i.e., inducing seizures). The same names are used in the student PNP to ensure that search in the prototype is reliable. Besides basic metadata, the content author can input more additional metadata by selecting the advanced DRD editing button. Examples of these extra metadata include the educational level of the LO or additional details about the nature of the adaptation. Student DRDs are stored as XML files that can be exported for reuse in other systems.

B. PERSONAL NEEDS AND PREFERENCES (PNP)

Students must enter their PNPs during the registration process so that the required adaptations of the LOs are presented. The application shows to the students a form which is used to build their PNPs. Fig. 2 shows an example of a PNP configuration for a deaf student. The student has selected textual and visual as access modes, alternative text and captions as adaptation types, and English and Spanish as preferred languages. Sign language and long descriptions have also been selected for the adaptation type (not shown in the figure).

Students use a simple form that facilitates the use of the adapted platform, although there is also the possibility of accessing a more detailed description of PNPs. Nevertheless, initially, the remaining options are filled with default values.

Moreover, to improve even more the ease of use, students have the chance to build their PNP profiles using a template that includes all profile features, such as blindness or deafness. PNPs are stored in XML files that can be exported and reused in other systems. An adapted LP can be used not only for students with different capacities but also for everybody in a challenging environment, such as a very noisy room or an environment with poor lighting. Thus, multiple PNPs can be provided for each student, although only one of them can be active at a given moment. Students activate the appropriate PNP depending on the environment where they are located when accessing the adapted platform.

C. SEARCH OF ADAPTED LEARNING OBJECTS

After completing the first two stages, a student is ready to access the adapted course resources. When students select a resource, the prototype (1) extracts data from the active PNP in their user profile; (2) then it searches for adapted LOs that meet the PNP; and (3) displays a list of all the adapted LOs found. Fig. 3 presents an example of a search query.

Fig. 4 shows a screenshot displaying the list of oscilloscope resources adapted for blind students and offered on the adapted platform. These resources include a long description of the images, a long description of the images and sound, and an audio description of the images together with the sound of the video.

```
SELECT DISTINCT
        drd_ressource.drd_ressource_id As DRDID,
        drd_ressource.drd_ressource_name As DRDName,
        drd_ressource1.drd_ressource_name As OriginalName,
        drd_ressource1.drd_ressource_id As OriginalID,
        pnp_profile.pnp_profile_id As ProfileID,
        pnp_profile.pnp_profile_name As ProfileName
FROM drd_ressource
 Inner Join ...
```

FIGURE 3. Sample of the search code for adapted LOs.

FIGURE 4. Oscilloscope video tutorial adaptations shown for blind students.

IV. METHOD

The research method was designed to assess the attitude of the students who use the adapted LP prototype. The aim of this paper is to compare the results of two groups of students (blind and deaf) concerning the satisfaction with usability and usefulness of the adapted LP; therefore, we formulated

the following research question: "*Is student's perception of satisfaction with learning experience (accessibility and adaptability) and usability of the platform (ease of use and usefulness) influenced by adaptation of learning contents?*"

We answered the research question through the analysis of student responses to a questionnaire.

A. PARTICIPANTS

The number of participants with different capacities who took part in the study was 23: 10 blind, 10 deaf, and 3 deaf-blind. It was challenging to obtain a large study sample because only a part of the population is affected by functional diversity, and this segment is not integrated into society. There were 3 blind women and 4 deaf women in the sample. The participants' age ranged from 24 to 55. From the 23 students, 22 were teachers in organizations for blind and deaf people. One participant was a computer expert and had a substantial experience using computers. Another 5 participants used a computer frequently, but the rest of the participants were infrequent computer users. All participants were informed and gave consent to participate in the experiment. This research gathered personal data of participants following the European regulation. Participants were informed about their rights to opt-out of the experiment and to access, rectify or cancel their personal data. Data was anonymized for analysis. The protocol, consent and information sheet for participants were approved by the ethical committee of the project.

B. MATERIALS

The Moodle platform was chosen for adaptation considering the advantages reported by a study [68] that contrasted a wide range of factors on the existing LPs. Our prototype was programmed in PHP, which is the working programming language of Moodle, and used the MySQL database to store PNPs and DRDs.

The topics selected for creating the educational materials were "use of an oscilloscope" and "communication networks", which are related to technical courses. We chose these content topics because of the accessibility problems that experimental learning materials usually present, such as the use of the oscilloscope. The learning content was presented using trial short course consisting of two video tutorials and their adaptations, which included visual and auditory information and presented the use of an oscilloscope as well as the topology and operation of communication networks.

Figs. 5 and 6 show the subtitles created for the oscilloscope video adaptation and the subtitles and sign language used to adapt the communication networks video. Fig. 5 represents the oscilloscope. An arrow points the button while the teacher explains its function, and the subtitles summarize the explanation: "With this button, we can modify the wavelength". Fig. 6 shows a computer network. In this case, the teacher explains the classification of different computer networks, and talks about LAN networks: "Computer networks are classified according to their range as local area networks or LAN".

FIGURE 5. Oscilloscope video subtitles inserted in adapted LOs.
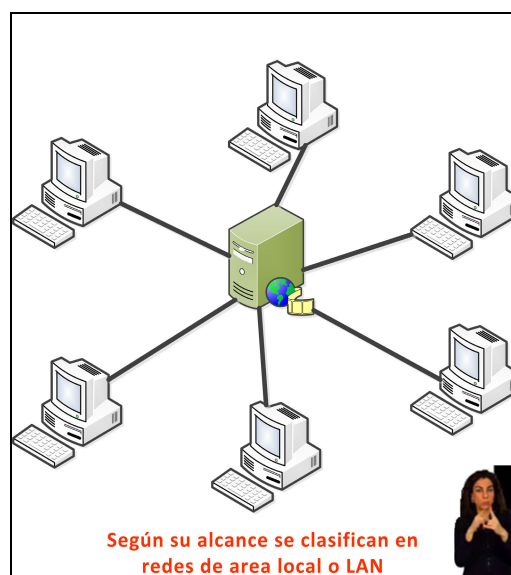
FIGURE 6. Computer network video subtitles and sign language inserted in the adapted LOs.

We generated the following set of adaptations for the videos so that students could access visual and auditory information:

1. Audio description
2. Captions
3. Sign language
4. Long description of images, which is reproduced as audio speech by a screen reader.
5. Long description of images and audio for deaf-blind students, which is transcribed to braille by a screen-reader and a braille device.

Figs. 6 and 7 show the images of the video tutorial providing visual information about communication.

The English translation and full description of fig. 8 are as follows: The picture shows the seven layers of the OSI (Open System Interconnection) model and it is divided into two parts located on the left and right sides of the illustration.

FIGURE 7. Image in the video showing a type of communication.

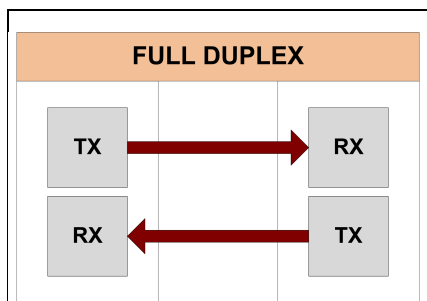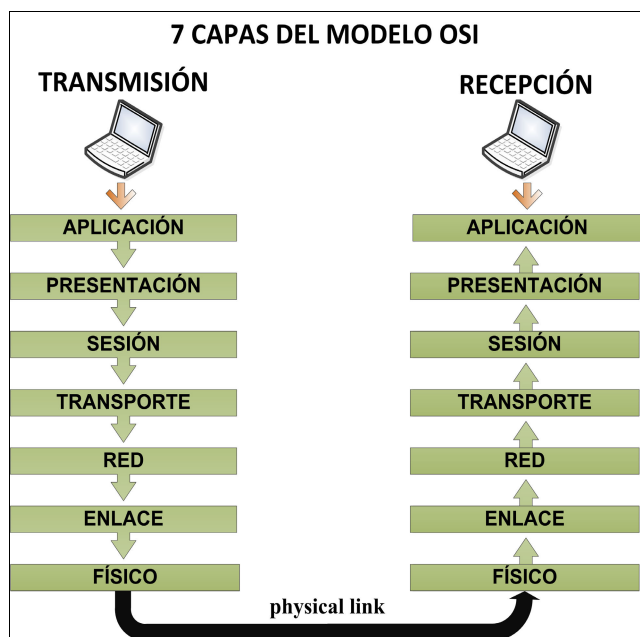**FIGURE 8.** Image in the video showing a reference model for communication protocols.

The text "7 layers of the OSI model" is shown in the center at the top of the image, and the words "Transmission" and "Reception" are written at the top of the left and right-hand sides of the illustration. Each layer is represented by a rectangle (on the two sides of the image) which also shows the direction of the data flow. Every rectangle has the name of the layer written down. These are: Application, Presentation, Session, Transport, Network, Data Link and Physical. The left-hand side depicts the data transmission process from the moment the user enters the data, to the physical layer. The right-hand side is the counterpart of the left-hand side, and displays the data reception process, from the physical layer to the user. An arrow at the bottom of the picture connects the transmission side to the reception side and bears the word "physical link".

C. PROCEDURE

The empirical study was run during the fall term of 2014. Preparatory stages included analyzing the usability aspect of the Moodle LP. We found that students and teachers were satisfied with Moodle LP [69], reporting an acceptable starting level of usability concerning ease of use and efficiency [70]. We also carried out an expert review of Moodle usability [71] which was conducted by a professional on blind accessibility.

The first step of the experimental procedure consisted on the reviewing of computers, assistive technology (screen reader and braille device), and the Internet connection. The study was supervised by four specialists, who tutored the learning action and were available to help students if they had questions about the learning process or if they experienced technical problems with the computer. We instructed tutors about the actions to be performed so students were able to complete the learning process and answer to the attitudinal questionnaire. The initial steps included:

1. Registration of the students on the LP using a username and password.
2. Creation and activation of their PNP profiles.
3. Selection of the course.

Students accessed the LOs through the platform without adaptation, and after that, they accessed the LOs through the adapted platform (using assistive technologies in both cases), so students could clearly experience the difference between both [11]. The procedure was explained to the students at the beginning of the session. They were allowed to ask any questions or express any concern they might have, as well as to make suggestions to improve the application. Finally, students answered a 7-item questionnaire that gathered their opinions about the ease of use and usefulness of the adapted platform. The assessment instrument was a five-points Likert-scale from 5 (strongly agree) to 1 (strongly disagree). Students' answers were anonymous. The survey was designed considering previous works by [71] and [72] focusing on the adaptations. It included the next questions:

Q1. I was satisfied with the experience.

Q2. Using the adapted Moodle platform was easy.

Q3. I was satisfied with the adaptations to the LP.

Q4. I was able to access all the visual and auditory information of the videos.

Q5. The information was shown in an easy and intuitive way.

Q6. The degree of usefulness of the application is high.

Q7. This was a worthwhile learning experience.

V. RESULTS

This section reports the attitude of students towards the use and usefulness of the adapted LP prototype by analyzing the answers to the questionnaire. Most students rated questions between 3 to 5 (table 1 and fig. 9), which suggests a general positive attitude towards the adapted Moodle LP. The question that returned the lowest score was question 5. The reason for blind and deaf-blind students could be that they got the information without any reference to its position on the screen. Scores of deaf students may suggest an improvement in terms of the presentation of information.
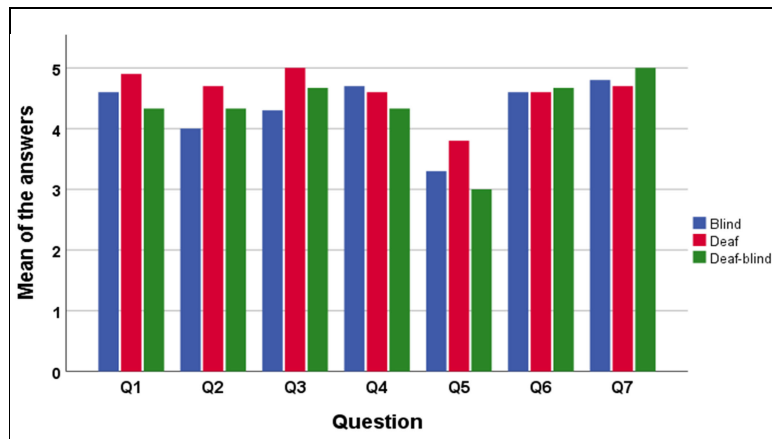
FIGURE 9. Answers to the attitudinal test for blind, deaf and deaf-blind students.

TABLE 1. Results of the attitudinal survey for the three groups.

Question	Blind			Deaf			Deaf-blind		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Q1	4.60	0.70	5	4.90	0.32	5	4.33	0.58	4
Q2	4	0.82	4	4.70	0.48	5	4.33	0.58	4
Q3	4.30	0.82	4.5	5	0.00	5	4.67	0.58	5
Q4	4.70	0.48	5	4.60	0.52	5	4.33	0.58	4
Q5	3.30	0.82	3	3.80	0.63	4	3	0.00	3
Q6	4.60	0.52	5	4.60	0.52	5	4.67	0.58	5
Q7	4.80	0.42	5	4.70	0.48	5	5	0.00	5
Average	**4.33**	**0.65**	-	**4.61**	**0.42**	-	**3.62**	**0.41**	-

Overall results werehomogeneous since the variability of the scores was low as shown by the average standard deviations (0.65, 0.42 and 0.41), which were less than 20% of the means (4.33, 4.61 and 3.62 respectively). Although variability was small, it was larger for the group of blind students than it was for the group of deaf students, except for questions 4 and 7 (table 1 and fig. 10). This could also be explained by the loss of perspective, although it cannot be generalized for all of the blind students since students with practice in computers can compensate it partly. Results returned a higher score for deaf students in all questions except Q4 and Q7 when compared with the blind group. Also, the question that the deaf students scored lowest was Q5. This suggests that deaf students found that information was presented in a more suitable form for their needs, and somehow that adaptations failed to convey information in an easy and intuitive way to blind students. Results of the deaf-blind group were not conclusive due to their small sample (3 students), although we want to point the low score for questions 1, 4 and 5.

We now present a statistical comparative analysis of the responses provided by the groups (blind and deaf) to the attitudinal survey. This study included seven continuous variables represented by the seven questions (quantified by a Likert scale that is considered continuous since it is supposed a subjective continuous scale materialized in an ordinal preference scale) and a categorized factor with two levels (blind and deaf).
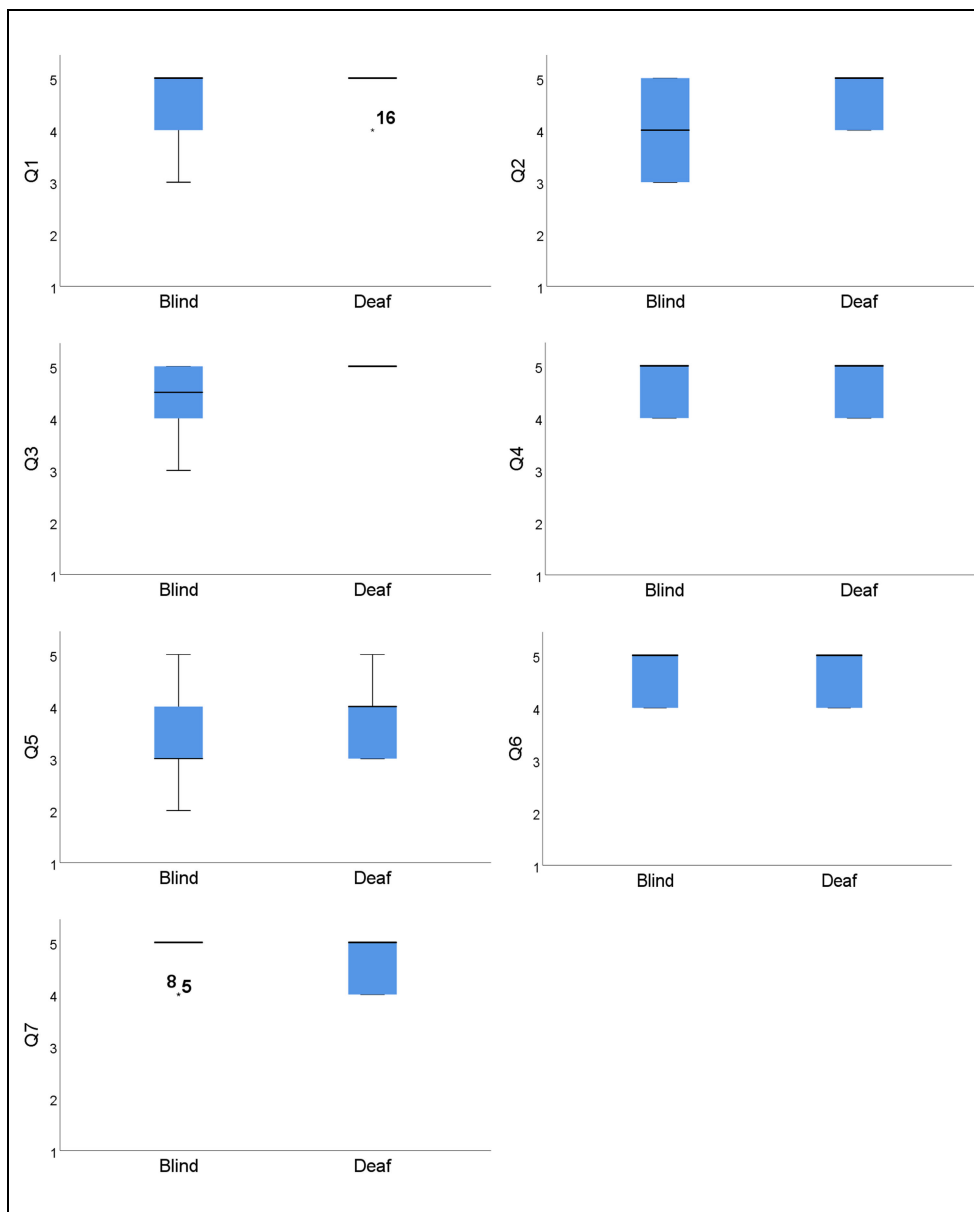
FIGURE 10. Box-plot diagram of the scores grouped by different type of different capacity.

TABLE 2. Results of the Kruskal-Wallis test comparing the blind and deaf groups.

	Q1	Q2	Q3	Q4	Q5	Q6	Q7
			Test Statistics[a,b]				
Kruskal-Wallis H	1.297	4.128	6.209	0.209	2.569	0.000	0.253
P-value	0.255	0.042	0.013	0.648	0.109	1.000	0.615

a. Kruskal Wallis Test

b. Grouping Variable: Different capacity

Shapiro-Wilk normality test indicated a non-normal distribution of the sample, implying that ANOVA analysis could not be used, so we took into account non-parametric tests. Results of a Kruskal-Wallis test (table 2) showed that the p-values of questions 2 and 3 (0.042 and 0.013 respectively) were less than 0.05 which demonstrated that there was a difference in these questions between groups. P-values of the rest of the questions were over 0.05 concluding that there

was no difference between the two groups in the answers to the rest of the questions. The difference in the answers to question 2 ("*Using the adapted Moodle platform was easy*") could be supported by the fact that eyesight is the only mean that can be used to navigate the LP. The difference in answers to question 3 ("*I was satisfied with the adaptations to the LP*") may be related to the criticism that blind students made to the audio-description of the resources. They suggested that descriptions were too long describing every small detail and making difficult to keep focus on the learning objective [73].

A gender analysis of the data showed that there were no significant differences in any of the questions between men and women (table 3). When considering the combination of gender and functional diversity factors, no differences were found either (table 4).

We used Cronbach's alpha reliability coefficient to assess the consistency of the scale used to measure the satisfaction of students with the adaptations. The generally agreed-upon lower limit for Cronbach's alpha is 0.7, although it may decrease to 0.6 in exploratory research [74]. When considering the data provided by the individuals in the two groups studied (blind and deaf), Cronbach's alpha was 0.649. We also computed the Cronbach's alpha deleting each item to assess whether all the items in the questionnaire measure the same construct. Table 5 shows the change in Cronbach's alpha when each question is omitted. Only deleting Q1 could improve the coefficient, but in such a short amount that it is better to keep Q1 in the scale.

VI. DISCUSSION AND CONCLUSION

Accessibility and usability are two interacting features that can impact each other when specific technical aspects are addressed. The adaptations of LPs present the potential to notably improve accessibility in education. The following factors should be considered when adapting an LP: LOs, their adaptations, accessibility metadata for both LOs and adaptations, student PNPs, and the search mechanisms employed to locate adapted LOs that meet student PNPs. There are also challenging environments such as noisy or poorly lighted rooms, where the adapted LP would be useful for everyone. Using an adapted LP requires that the content creator or teacher generates and uploads the LO adaptations to the platform with their accessibility metadata. In addition, students should store their PNPs in their profile.

In order to answer the research question: "*Is student's perception of satisfaction with learning experience (accessibility and adaptability) and usability of the platform (ease of use and usefulness) influenced by adaptation of learning contents?*", students, after using the platform and the adapted LOs, completed a questionnaire to assess their experience with the adapted LP prototype and the LOs. All the questions got a high average score (between 4 and 5) in a 5-point Likert scale, except question 5 ("The information was shown in an easy and intuitive way"). This indicates that students had a very positive attitude indeed towards the adapted platform.

They also pointed out to the significant improvement that the application would bring to their learning experience.

Results of the comparative statistical analysis of the questionnaire enable us to answer the research question. We can affirm that there was no difference between blind and deaf students in answers to questions 1, 4, 5, 6 and 7, meaning that (1) all students had a similar level of satisfaction with the experience considering it a valuable training; (2) they could get all the visual and auditory information; (3) they had a uniform opinion on the design of the interface' application perceiving an improvement in the way contents were presented, and (4) they felt a substantial level of effectiveness and usefulness of the adapted LP. However, we observed differences in answers to questions 2 and 3. For question 2 differences may occur because hearing is not used when interacting with the LP. In addition, blind students heartily concurred that the visual descriptions provided should only contain information relevant to learning, since (as in the case of the network videos) excessive information was confusing and distracting. This finding is consistent with the fact that people without vision problems, when presented with visual information like images, overlook irrelevant information focusing on the important content.

The observed bias in the blind group reflected in the better scores given to questions by the blind student with more expertise in computers reveals that the main obstacle to access the information through the adapted platform for blind students may be the lack of practice with computers.

We also observed during the study that at least half of the students faced problems when signing on the platform and asked for help to input the LP. Only after dealing with these issues students were able to access the course LOs. We realized by talking with them, observing considerable differences in the time taken to access to the platform which were related to their background and experience in using computers. We noticed that students experienced more problems when trying to log into the platform, which had no adaptation, than when interacting with the adapted LOs. This emphasizes the positive results obtained from the use of the adapted LP and also substantiates the usefulness of the adaptation. Despite the possible accessibility problems during log in, which can difficult the start of the learning process, students perceived that the use of the adapted platform and the adapted LOs was as a complete learning experience. No significant gender differences were found across all questions, either grouping participants by functional diversity or not.

Results of the attitudinal survey then suggest that accessible online education helps deaf and blind students, positively influencing their attitude towards learning positively. The main question about the validity of this study is the number of students in the sample. In our opinion, 23 students are a sufficient sample for an accessibility setting where it is difficult to find students with different capacities. It is also close to 30 which is a sample size accepted by the accessibility research community. However, as there were only three participants in the deaf-blind group, this group would require

TABLE 3. Results of the Kruskal-Wallis test comparing the female and male.

Test Statistics[a,b]							
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Kruskal-Wallis H	0.323	0.153	0.393	0.186	1.561	1.253	1.740
Asymp. Sig.	0.570	0.696	0.531	0.666	0.212	0.263	0.187
a. Kruskal Wallis Test							
b. Grouping Variable: Gender							

TABLE 4. Results of the Kruskal-Wallis test grouping by the combination of gender and different capacity.

Test Statistics[a,b]							
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
Kruskal-Wallis H	4.369	4.172	6.499	2.098	4.600	1.470	1.990
Asymp. Sig.	0.224	0.243	0.090	0.552	0.204	0.689	0.574
a. Kruskal Wallis Test							
b. Grouping Variable: Gender-Capacity							

TABLE 5. Item analysis of the questionnaire omitting each item (Alpha Cronbach 0.649).

Question	Cronbach's Alpha if Item Deleted
Q1 (Satisfaction with the experience)	0.655
Q2 (Ease of use of the platform)	0.533
Q3 (Satisfaction with the adaptations)	0.613
Q4 (Ability to access all the information)	0.649
Q5 (Information showed in an intuitive way)	0.583
Q6 (High degree of usefulness)	0.626
Q7 (Worthwhileness of the experience)	0.604

further research [75]. We used Cronbach's alpha reliability coefficient to assess the consistency of the attitudinal survey. Cronbach's alpha calculation, considering blind and deaf students together, was 0.649, which is acceptable for exploratory research. Removing specific questions yielded only marginal or no improvements, suggesting that the instrument was reliable for the given sample.

The results of our attitudinal survey are aligned with the results of studies that test different applications for people with functional diversity. For instance, T-learning, which is a Moodle-based system specially adapted for people with special needs by combining TV with Internet worlds [61], gives similar results. T-Learning assessed the ease of reading, the textual context, the visualization of different media contents, the quality of the videos, and the accessibility and ease of use of the assessment tools. Findings show that all of them improve the learning ability of students.

Although the study was conducted in 2014, we believe that results are valid today. Firstly, the adaptation of the platform is based on current international standards. Recent investigation in accessibility also points to accessibility metadata as a key enabling factor. Schema.org, the community responsible for creating, maintaining, and promoting metadata schemas for structured data published on internet [76], defined a set of accessibility metadata, based on IMS AFA 3.0, to describe digital resources. This schema was endorsed by W3C in 2015 and it is currently used by Google, Yahoo, Bing and Yandex among others [77]. This supports the current validity of our results, which are based on standard accessibility metadata while our adaptation is also prepared to accept other accessibility metadata if needed. We also argue that results of this study are still valid because learning platforms have mostly undergone technical updates in the last few years, so only minor software updates would be necessary, which we also addressed when our tool was developed. Finally, although we think that adapted standardized approaches motivate students to use learning platforms and contents, there are no similar accessibility studies [67]

that test and compare students' perceptions with a prototype learning platform adapted to multiple different capacities (blind and deaf in this study) and that is also compliant with current recommendations.

REFERENCES

[1] G. O. Young, A. Sangrá, D. Vlachopoulos, and N. Cabrera, "Building an inclusive definition of e-learning: An approach to the conceptual framework," *Int. Rev. Res. Open Distrib. Learn.*, vol. 13, no. 2, pp. 145–159, 2012, doi: 10.19173/irrodl.v13i2.1161.

[2] S. Burgstahler, T. Jirikowic, B. Kolko, and M. Eliot, "Software accessibility, usability testing and individuals with disabilities," *Inf. Technol. Disabilities*, vol. 10, pp. 1–2, Dec. 2004.

[3] F. Kareal and J. Klema, "Adaptivity in e-learning," in *Proc. Current Develop. Technol.-Assisted Educ.*, 2006, pp. 260–264.

[4] I. Dahlstrom-Hakki, Z. Alstad, and M. Banerjee, "Comparing synchronous and asynchronous online discussions for students with disabilities: The impact of social presence," *Comput. Educ.*, vol. 150, Jun. 2020, Art. no. 103842.

[5] B. W. Brown and C. E. Liedholm, "Student preferences in using online learning resources," *Social Sci. Comput. Rev.*, vol. 22, no. 4, pp. 479–492, Nov. 2004.

[6] C. Batanero, L. Fernández-Sanz, A. K. Piironen, J. Holvikivi, J. R. Hilera, S. Otón, and J. Alonso, "Accessible platforms for e-learning: A case study," *Comput. Appl. Eng. Educ.*, vol. 25, no. 6, pp. 1018–1037, Nov. 2017, doi: 10.1002/cae.21852.

[7] L. Nacheva-Skopalik and S. Green, "Intelligent adaptable E-assessment for inclusive e-learning," in *Management Association Learning and Performance Assessment: Concepts, Methodologies, Tools, and Applications*. Hershey, PA, USA: IGI Global, 2020, pp. 1185–1199, doi: 10.4018/978-1-7998-0420-8.ch056.

[8] A. B. Rajendra, N. Rajkumar, S. N. Bhat, T. R. Suhas, and S. P. N. Joshi, "E-learning web accessibility framework for deaf/blind Kannada-speaking disabled people," in *Proc. ICRIC* Cham, Switzerland: Springer, 2020, pp. 595–604, doi: 10.1007/978-3-030-29407-6_42.

[9] M. Hammad, M. Alnabhan, I. Abu Abu Doush, G. M. Alsalem, F. A. Al-Alem, and M. Mahmoud Al-Awadi, "Evaluating usability and content accessibility for e-learning websites in the Middle East," *Int. J. Technol. Hum. Interact.*, vol. 16, no. 1, pp. 54–62, Jan. 2020, doi: 10.4018/IJTHI.2020010104.

[10] S. Mirri, P. Salomoni, M. Roccetti, and G. Gay, "Beyond standards: Unleashing accessibility on a learning content management system," in *Transactions on Edutainment*, Z. Pan, A. Cheok, W. Müller X. Yang, Eds. Berlin, Germany: Springer, 2011, pp. 35–49, doi: 10.1007/978-3-642-18452-9_2.

[11] C. Batanero, L. de-Marcos, J. Holvikivi, J. R. Hilera, and S. Oton, "Effects of new supportive technologies for blind and deaf engineering students in online learning," *IEEE Trans. Educ.*, vol. 62, no. 4, pp. 270–277, Nov. 2019, doi: 10.1109/TE.2019.2899545.

[12] A. M. O. Mohammed, M. A. A. Mohmmed, and A. M. Osman, "Difficulties facing the integration of people with motor disabilities in formal education at the basic stage-South Darfur (2018–2019)," vol. 4, no. 5, 2020.

[13] S. Dey, R. Mukherjee, and A. Basu, "Embedded Sanyog: A portable communication tool for people with multiple disabilities," in *Proc. EISE*, Bangalore, India, Oct. 2009, pp. 53–62.

[14] A. Sesin, M. Adjouadi, M. Ayala, M. Cabrerizo, and A. Barreto, "Eyeing a real-time human-computer interface to assist those with motor disabilities," *IEEE Potentials*, vol. 27, no. 3, pp. 19–25, May 2008, doi: 10.1109/MPOT.2007.914733.

[15] H. Petrie and O. Kheir, "The relationship between accessibility and usability of websites," in *Proc. SIGCHI Conf. Hum. Factors Comput. Syst.*, Apr. 2007, pp. 397–406, doi: 10.1145/1240624.1240688.

[16] S. Iwarsson and A. Ståhl, "Accessibility, usability and universal design—Positioning and definition of concepts describing person-environment relationships," *Disability Rehabil.*, vol. 25, no. 2, pp. 57–66, Jan. 2003, doi: 10.1080/dre.25.2.57.66.

[17] N. Di Blas, P. Paolini, and M. Speroni, "Usable accessibility," to the web for blind users," in *Proc. 8th ERCIM Workshop, User Interfaces All*, Vienna, Austria, Jun. 2004, pp. 397–406.

[18] B. Shneiderman, "Promoting universal usability with multi-layer interface design," *ACM SIGCAPH Comput. Physically Handicapped*, vol. 17, pp. 73–74, Jun. 2002, doi: 10.1145/960201.957206.

[19] B. Leporini and F. Paterná, "Applying web usability criteria for vision-impaired users: Does it really improve task performance?" *Int. J. Hum.-Comput. Interact.*, vol. 24, no. 1, pp. 17–47, Jan. 2008, doi: 10.1080/10447310701771472.

[20] L. Tateo, "Web accessibility and usability: Limits and perspectives," in *Proc. 1st Workshop Technol. Enhanced Learn. Environ. Blended Educ.*, Jan. 2021, pp. 1–2.

[21] The World Wide Web Consortium (W3C). *Web Accessibility Initiative (WAI)*. Accessed: Mar. 3, 2021. [Online]. Available: https://www.w3.org/WAI/fundamentals/accessibility-usability-inclusion/.

[22] *The World Wide Web Consortium (W3C)*. Accessed: May 1, 2019. [Online]. Available: https://www.w3.org/

[23] C. Waddell, B. Regan, S. L. Henry, M. R. Burks, J. Thatcher, M. D. Urban, and P. Bohman, *Constructing Accessible Web Sites*. New York, NY, USA: Apress, 2003.

[24] M. G. Jones, J. Minogue, T. Oppewal, M. P. Cook, and B. Broadwell, "Visualizing without vision at the microscale: Students with visual impairments explore cells with touch," *J. Sci. Educ. Technol.*, vol. 15, nos. 5–6, pp. 345–351, Nov. 2006, doi: 10.1007/s10956-006-9022-6.

[25] O. Lahav, N. Hagab, S. A. El Kader, S. T. Levy, and V. Talis, "Listen to the models: Sonified learning models for people who are blind," *Comput. Educ.*, vol. 127, pp. 141–153, Dec. 2018.

[26] M. A. De Leo-Winkler, G. Wilson, W. Green, L. Chute, E. Henderson, and T. Mitchell, "The vibrating universe: Astronomy for the deaf," *J. Sci. Educ. Technol.*, vol. 28, no. 3, pp. 222–230, Jun. 2019, doi: 10.1007/s10956-018-9761-1.

[27] A. Zafra, E. Gibaja, M. Luque, and S. Ventura, "An evaluation of the effectiveness of e-learning system as support for traditional classes," in *Proc. 7th Int. Conf. Next Gener. Web Services Practices*, Salamanca, Spain, Oct. 2011, pp. 431–435, doi: 10.1109/NWeSP.2011.6088218.

[28] N. Kipkurui, P. G., and A. Ikoha, "Evaluating usability of e-learning systems in universities," *Int. J. Adv. Comput. Sci. Appl.*, vol. 5, no. 8, pp. 97–102, 2014.

[29] K. Foley, A. Alturkistani, A. Carter, T. Stenfors, E. Blum, J. Car, A. Majeed, D. Brindley, and E. Meinert, "Massive open online courses (MOOC) evaluation methods: Protocol for a systematic review," *JMIR Res. Protocols*, vol. 8, no. 3, Mar. 2019, Art. no. e12087, doi: 10.2196/12087.

[30] A. Daniels and J. Downing, "Increasing access to children's palliative care education through e-learning: A review of the ICPCN experience," *Int. J. Palliative Nursing*, vol. 24, no. 7, pp. 351–358, Jul. 2018, doi: 10.12968/ijpn.2018.24.7.351.

[31] M. Kent, K. Ellis, and M. Giles, "Students with disabilities and eLearning in australia: Experiences of accessibility and disclosure at curtin university," *TechTrends*, vol. 62, no. 6, pp. 654–663, Nov. 2018, doi: 10.1007/s11528-018-0337-y.

[32] A. P. Freire, R. P. de Mattos Fortes, D. M. B. Paiva, and M. A. S. Turine, "Using screen readers to reinforce web accessibility education," *ACM SIGCSE Bull.*, vol. 39, no. 3, pp. 82–86, Jun. 2007, doi: 10.1145/1269900.1268810.

[33] S. Lewthwaite and D. Sloan, "Exploring pedagogical culture for accessibility education in computing science," in *Proc. 13th Int. Web Conf.*, Montreal, QC, Canada, Apr. 2016, pp. 1–4, doi: 10.1145/2899475.2899490.

[34] J. Seale, J. Georgeson, C. Mamas, and J. Swain, "Not the right kind of 'digital capital'? An examination of the complex relationship between disabled students, their technologies and higher education institutions," *Comput. Educ.*, vol. 82, pp. 118–128, Mar. 2015, doi: 10.1016/j.compedu.2014.11.007.

[35] P. W. Dowrick, J. Anderson, K. Heyer, and J. Acosta, "Postsecondary education across the USA: Experiences of adults with disabilities," *J. Vocational Rehabil.*, vol. 22, no. 1, pp. 41–47, 2005.

[36] U. T. Alturki, A. Aldraiweesh, and D. Kinshuck, "Evaluating the usability and accessibility of LMS 'Blackboard' at King Saud University," *Contemp. Educ. Res.*, vol. 9, no. 1, pp. 33–44, Jan. 2016, doi: 10.19030/cier.v9i1.9548.

[37] T. Armano, M. Borsero, A. Capietto, N. Murru, A. Panzarea, and A. Ruighi, "On the accessibility of Moodle 2 by visually impaired users, with a focus on mathematical content," *Universal Access Inf. Soc.*, vol. 17, no. 4, pp. 865–874, Nov. 2018, doi: 10.1007/s10209-017-0546-8.

[38] T. Acosta and S. Luján-Mora, "Comparison from the levels of accessibility on LMS platforms that supports the online learning system," in *Proc. Edulearn*, Barcelona, Spain, Jul. 2016, pp. 2704–2711, doi: 10.21125/edulearn.2016.1579.

[39] P. Lorca, J. D. Andrés, and A. B. Martínez, "The relationship between web content and web accessibility at universities: The influence of social and cultural factors," *Social Sci. Comput. Rev.*, vol. 36, no. 3, pp. 311–330, Jun. 2018.

[40] T. Acosta, P. Acosta-Vargas, L. Salvador-Ullauri, and S. Luján-Mora, "Method for accessibility assessment of online content editors," in *Proc. Int. Conf. Inf. Theoretic Secur.* Cham, Switzerland: Springer, Jan. 2018, pp. 538–551, doi: 10.1007/978-3-319-73450-7_51.

[41] G. Brajnik, Y. Yesilada, and S. Harper, "The expertise effect on web accessibility evaluation methods," *Hum.-Comput. Interact.*, vol. 26, no. 3, pp. 246–283, 2011.

[42] M. Arrue, X. Valencia, J. E. Pérez, L. Moreno, and J. Abascal, "Inclusive web empirical studies in remote and *in-situ* settings: A user evaluation of the RemoTest platform," *Int. J. Hum.–Comput. Interact.*, vol. 35, no. 7, pp. 568–583, Apr. 2019, doi: 10.1080/10447318.2018.1473941.

[43] M. Campoverde-Molina, S. Lujan-Mora, and L. V. Garcia, "Empirical studies on web accessibility of educational websites: A systematic literature review," *IEEE Access*, vol. 8, pp. 91676–91700, 2020.

[44] World Wide Web Consortium (W3C). *Web Content Accessibility Guidelines (WCAG) 3.0*. Accessed: May 11, 2021. [Online]. Available: https://www.w3.org/TR/2021/WD-wcag-3.0-20210121/

[45] (2006). *The Global Initiative for Inclusive Information and Communication Technologies, Concourse Parkway, Suite 800, Atlanta, Georgia 30328, United States of America*, Accessed: Apr. 25, 2019. [Online]. Available: https://g3ict.org/

[46] United Nations. (2006). *Convention on the Rights of Persons with Disabilities*. Accessed: Apr. 26, 2019. [Online]. Available: http://www.un.org/disabilities/convention/

[47] *European Agency for Special Needs and Inclusive Education*. Accessed: Apr. 24, 2019. [Online]. Available: https://www.european-agency.org/

[48] *U.S. Department of Education*, Accessibility Maryland Avenue, SW, Washington, DC, USA. 20202. Accessed: Apr. 26, 2019. [Online]. Available: https://www.ed.gov/category/keyword/accessibility

[49] ECOMODE Project and European Commission. (2018). *Technology for People With Visual and Hearing Impairments, Programme Horizon 2020*. Accessed: Apr. 16, 2019. [Online]. Available: https://ec.europa.eu/digital-single-market/en/content/ecomode

[50] Easy Reading project. (2020). *Technology for People with Cognitive, Learning and Neurological Impairments, Programme Horizon 2020*. Accessed: Apr. 15, 2019. [Online]. Available: https://ec.europa.eu/digital-single-market/en/content/easy-reading

[51] InLife Project. (2018). *Technology for People With Cognitive, Learning and Neurological Impairments, Programme Horizon 2020*. Accessed: May 14, 2019. [Online]. Available: https://ec.europa.eu/digital-single-market/en/content/inlife

[52] WAI-Guide Project. (2021). *Accessible Information and Communication Technology, Programme Horizon 2020*. Accessed: Apr. 15, 2019. [Online]. Available: https://ec.europa.eu/digital-single-market/en/content/wai-guide

[53] WADcher Project. (2020). *Accessible Information and Communication Technology, Programme Horizon 2020*. Accessed: Apr. 17, 2019. [Online]. Available: https://ec.europa.eu/digital-single-market/en/content/wadcher

[54] IMS, Global Learning Consortium. (2004). *IMS AccessForAll Meta-data Specification, Version 1*. Accessed: May 2, 2019. [Online]. Available: http://www.imsglobal.org/accessibility/#accmd

[55] *Information Technology–Individualized Adaptability and Accessibility in E-Learning Education and Training*, Standard ISO/IEC 24751-1-2-3, International Standard Organization, 2018. Accessed: Jun. 11, 2019. [Online]. Available: https://www.iso.org/standard/41521.html

[56] M. Laabidi, M. Jemni, L. Jemni Ben Ayed, H. Ben Brahim, and A. Ben Jemaa, "Learning technologies for people with disabilities," *J. King Saud Univ.-Comput. Inf. Sci.*, vol. 26, no. 1, pp. 29–45, Jan. 2014, doi: 10.1016/j.jksuci.2013.10.005.

[57] IMS. (2009). *Global Learning Consortium*, Accessed: May 3, 2019. [Online]. Available: http://www.imsglobal.org/accessibility/#accDRD

[58] A. Rodriguez-Ascaso, J. G. Boticario, C. Finat, and H. Petrie, "Setting accessibility preferences about learning objects within adaptive elearning systems: User experience and organizational aspects," *Expert Syst.*, vol. 34, Aug. 2017, Art. no. e12187, doi: 10.1111/exsy.12187.

[59] C. Batanero, J. Holvikivi, S. Otón, and J. Alonso, "Considering student personal needs and preferences and accessible learning objects to adapt moodle learning platform," in *Proc. 23 rd. Int. Conf. Inf. Syst. Develop. (ISD)*, Varadin, Croatia, 2014, pp. 150–158.

[60] IMS. (2012). *Global Learning Consortium. IMS AccessForAll v3.0 Public Draft Specification*. Accessed: May 7, 2019. [Online]. Available: http://www.imsglobal.org/accessibility/#afav3

[61] C. R. Costa, M. G. Carballa, and L. E. Anido-Rifón, "T-learning para personas con discapacidad," *IEEE-RITA*, vol. 7, no. 2, pp. 70–77, Apr. 2012.

[62] D. Giakoumis, N. Kaklanis, K. Votis, and D. Tzovaras, "Enabling user interface developers to experience accessibility limitations through visual, hearing, physical and cognitive impairment simulation," *Universal Access Inf. Soc.*, vol. 13, no. 2, pp. 227–248, Jun. 2014, doi: 10.1007/s10209-013-0309-0.

[63] T. Acosta, J. Zambrano-Miranda, and S. Lujan-Mora, "Techniques for the publication of accessible multimedia content on the web," *IEEE Access*, vol. 8, pp. 55300–55322, 2020.

[64] S. Raptis and P. Kakoulidis, "Enhancing the accessibility of e-learning platforms through synthetic speech," in *Proc. 20th Pan-Hellenic Conf. Informat.* Patras, Greece: ACM, Nov. 2016, pp. 1–4, doi: 10.1145/3003733.3003763.

[65] A. Segal, K. Gal, G. Shani, and B. Shapira, "A difficulty ranking approach to personalization in e-learning," *Int. J. Hum.-Comput. Stud.*, vol. 130, pp. 261–272, Oct. 2019.

[66] C. Morrison, N. Villar, A. Hadwen-Bennett, T. Regan, D. Cletheroe, A. Thieme, and S. Sentance, "Physical programming for blind and low vision children at scale," *Hum.-Comput. Interact.*, pp. 1–35, Jul. 2019.

[67] M. Tomaino, A. L. Greenberg, S. A. Kagawa-Purohit, S. Doering, and E. S. Miguel, "An assessment of the feasibility and effectiveness of distance learning for students with severe developmental disabilities and high behavioral needs," *Behav. Anal. Pract.*, vol. 4, pp. 1–17, Mar. 2017.

[68] F. Afonso and H. R. Amado Salvatierra, "Requisitos de accesibilidad de un campus virtual," in *Proc. Guía metodológica para la Implantación de Desarrollos Curriculares Virtuales Accesibles: Proyecto ESVI-AL*, 2013, pp. 111–136.

[69] M. Ivanovic, Z. Putnik, Z. Komlenov, T. Welzer, M. Hölbl, and T. Schweighofer, "Usability and privacy aspects of Moodle: Students' and teachers' perspective," *Informatica*, vol. 37, no. 3, pp. 221–230, 2013.

[70] G. Kakasevski, M. Mihajlov, S. Arsenovski, and S. Chungurski, "Evaluating usability in learning management system moodle," in *Proc. 30th Int. Conf. Inf. Technol. Interface*, Dubrovnik, Croatia, Jun. 2008, pp. 613–618, doi: 10.1109/ITI.2008.4588480.

[71] D. A. Cook and D. M. Dupras, "A practical guide to developing effective web-based learning," *J. Gen. Internal Med.*, vol. 19, no. 6, pp. 698–707, Jun. 2004, doi: 10.1111/j.1525-1497.2004.30029.x.

[72] G. K. Akilli, "User satisfaction evaluation of an educational website," *Turkish Online J. Educ. Technol.*, vol. 4, no. 1, pp. 85–92, 2005.

[73] S. Giraud, P. Thérouanne, and D. D. Steiner, "Web accessibility: Filtering redundant and irrelevant information improves website usability for blind users," *Int. J. Hum.-Comput. Stud.*, vol. 111, pp. 23–35, Mar. 2018.

[74] J. P. Robinson, P. R. Shaver, and L. S. Wrightsman, "Criteria for scale selection and evaluation," in *Measures of Personality and Social Psychological Attitudes*, J. P. Robinson, P. R. Shaver, and L. S. Wrightsman, Eds. San Diego, CA, USA: Academic, 1991.

[75] E. Perfect, A. Jaiswal, and T. C. Davies, "Systematic review: Investigating the effectiveness of assistive technology to enable Internet access for individuals with deafblindness," *Assistive Technol.*, vol. 31, no. 5, pp. 276–285, 2019, doi: 10.1080/10400435.2018.1445136.

[76] (2021). *Schema*. Accessed: May 11, 2021. [Online]. Available: https://www.schema.org/

[77] S. Otón, P. Ingavelez, S. Sanchez-Gordon, and M. Sánchez-Gordán, "Evolution of accessibility metadata in educational resources," in *UXD and UCD Approaches for Accessible Education*. Hershey, PA, USA: IGI Global, 2020, pp. 1–20.

CONCEPCIÓN BATANERO-OCHAÍTA received the master's degree in computers with a focus on electronic teaching and learning from Alcalá University, in 2009, and the master's degree in neuroscience and behavior biology from the Pablo de Olavide University, in 2011. She is currently a Lecturer with Alcalá University. Her current research focuses on accessibility in education at Alcalá University, collaborating in this area with the ESVI-AL, WAMDIA, and EduTech projects about accessible virtual education, granted by the European Union. She was working ten years in private companies in engineering area.

JAANA HOLVIKIVI received the Ph.D. degree in information technology from the Helsinki University of Technology, Finland. Her career has expanded to four continents when working within the United Nations system in various development projects. Recently, she was a Principal Lecturer in software education with the Metropolia University of Applied Sciences, Helsinki. Her research interests include software education in cross-cultural context, student diversity issues, project-based and agile learning methods, and cognitive science. She currently chairs the IFIP Working Group 3.4 for Professional, Higher and Vocational Education in ICT.

LUIS DE-MARCOS received the B.Sc. and M.Sc. degrees in computer science and the Ph.D. degree in information, documentation, and knowledge, in 2001, 2005, and 2009, respectively. Since 2015, he has been an Associate Professor with the University of Alcalá. He is currently the Principal Investigator of the H2020 ProTego Project (Data-protection toolkit reducing risks in hospitals, 2019–2021). He participated in the EU IAPP MC Project (Iceberg: 2013–2017), in two Erasmus Intensive programs (2009–2013), and two Erasmus+Strategic Partnership projects (2014–2017). He was a principal investigator in two national research projects (2011–2013). He was a Research Fellow with Lund University, Sweden, in 2007 and 2009; the University of Reading, U.K., in 2008; the Monterrey Institute of Technology, Mexico, in 2010; and the University of Zagreb, Croatia, in 2018. He has over 100 refereed publications in conferences and journals. His research interests include gamification, educational technologies, e-learning, and computer science education.

JOSÉ RAMÓN HILERA received the bachelor's degree from the Polytechnic University of Madrid and the Ph.D. degree in science from the University of Alcalá. He is currently a Telecommunication Engineer. He was a Lecturer with the Polytechnic University of Madrid. Then, he became a Full Professor with the Polytechnic School, University of Alcalá. He is also the Director of the master's program in software engineering for the Web and the Coordinator of the ESVI-AL Cooperation Network about Accessibility in Virtual Education, funded by the European Union's ALFA III Program. He has authored or coauthored over 150 scientific works (books, articles, papers, and research projects) and some related to learning technology and accessibility. Since their creation, he has organized several editions of two international conferences on accessibility, such as the International Conference on Quality and Accessibility in eLearning (CAFVIR), and the International Conference on Application of Information and Communications Technologies to improve Accessibility (ATICAcces).

LUIS FELIPE RIVERA received the B.Sc. degree in mathematics and computer science from the Complutense University of Madrid, Spain, and the Ph.D. degree in economics from the University of Alcalá, Spain. He is currently an Associate Professor of quantitative methods with the University of Alcalá, where he teaches statistical methods to undergraduate and postgraduate students. He is also a Research Associate with the Institute for Economic and Social Analysis, and the Institute of Latin American Studies, University of Alcalá. He has participated in several Spanish and European research projects. He is the author or coauthor of more than 70 scientific works (books, journal articles, conference papers, and research projects) related to statistical methods in psychology, business, and economics. His research interests include mathematical and statistical methods applied to social sciences and education.

SALVADOR OTÓN TORTOSA received the degree in computer science engineering from the University of Murcia, in 1996, and the Ph.D. degree from the University of Alcalá, in 2006. He is currently an Associate Professor with the Computer Science Department, University of Alcalá. He also coordinates the Master Agile Software Development for the Web. He is also the coordinator of the European Project EduTech about accessible virtual education, granted by the Erasmus+ Program of the European Union. He is the author or coauthor of more than 80 scientific works (books, articles, papers, and research projects), the majority of them directly related to learning technology, accessibility, and interoperability. His research interests include learning objects and e-learning standardization and mainly in accessibility, metadata, distributed learning objects repositories, interoperability, and enterprise architectures.

• • •