Higher Education Institutions and Learning Management Systems:

Adoption and Standardization

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Chapter 10
Disability Standards and Guidelines for Learning Management Systems:
Evaluating Accessibility

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ABSTRACT

Currently, the great majority of institutions of higher education use Learning Content Management Systems (LCMSs) and Learning Management Systems (LMS) as pedagogical tools. In order to make these systems accessible to all students, it is important to take into account not only educational standards, but also standards of accessibility. It is essential to have with procedures and well-established method for evaluating these tools, so in this paper we propose a method for evaluating the accessibility of LCMSs and LMS based on a consideration of particular accessibility standards and other technological and human aspects.

The method application is for all LMS, in order to illustrate the effectiveness of the evaluation method, we present a case study over the widely-used LMS Moodle[1]. In the case study, the accessibility of Moodle is evaluated thoroughly from the point of view of visually-impaired persons. The results obtained from the case study demonstrate that this LMS is partially accessible. The evaluation shows that the tool provides poor support to the authors of accessible educational contents.

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INTRODUCTION

Information and Communication Technology (ICT) plays a key role in people's daily lives (Rößling G. et al, 2008), a fact that is equally true of people with and without disabilities. Over the past few years in the education sector and, more specifically, in institutions of higher education, Learning Management Systems (LMS) and Learning Content Management Systems (LCMSs) have become extremely popular pedagogical tools for teachers and students. Such is the current popularity of LMS in these institutions, in fact, that LMS are oftentimes the only tool given to students for communicating with peers and teachers or for accessing particular learning resources. Therefore, the negative impact of an inaccessible LMS on the learning experience of students with disabilities would be large indeed. In order to provide equal opportunities to all students, it is necessary to improve the learning environment by removing all barriers to accessibility. LMS, LCMSs and their learning contents should be available to all students and teachers, including those with disabilities and regardless of their particular accessibility needs.

In the effort to make software completely accessible to all types of users, it must be taken into account that certain individuals require the use of Assistive Technologies (ATs) such as screen readers, refreshable Braille displays, speech synthesizers, magnifiers, adaptable keyboards or voice recognition software in order to see, hear, move or interact with the system and its contents. In addition to covering the widest range of user abilities, software should also take user preferences and learning styles (*e.g.*, visual, auditory or tactile) into account. The development of software in this way would allow all users, not just individuals with disabilities, to universally benefit from system contents (Moreno, L. et al, 2008). Therefore, in order to ensure the achievement of this goal in the context of institutions of higher learning, it is necessary to design and develop LMS and LCMSs according to standards that facilitate universal access and, at the same time, promote correct technological growth (Fichten, C.S., 2009). Moreover, evaluations of the accessibility of these LMS and LCMSs and the certification of their compliance with accessibility standards should also be required.

In the following section of this chapter, specific technologies, accessibility standards and previously published work regarding LMS accessibility is discussed at length. In the third section, a new method for the evaluation of the compliance of an LMS with previously examined accessibility standards is proposed. This evaluation method is then put into practice in the fourth section for the Moodle LMS whose accessibility, specifically for visually-impaired individuals, is tested by an accessibility expert and a visually-impaired end-user (with the assistance of JAWS screen reader). Finally, the fifth section presents briefly general conclusions from the case study as well as areas for future research.

BACKGROUND

For the present study, we have considered a wide variety of previous published works on accessibility standards and regulations, LMS incorporating accessibility requirements into their design, as well as studies of LMS accessibility evaluation methods. With regard to this last point, the user-centered design (UCD) approach is considered and developed here.

E-Learning and Accessibility Standards

In order to make educational resource applications and web sites universally accessible for all users, not only educational standards like the Sharable Content Object Reference Model (SCORM), but also accessibility standards like the Instructional Management System (IMS) guidelines for developing accessible learning applications[2], the World

Wide Web Consortium (W3C) standards[3], and the Web Accessibility Initiative (WAI) accessibility guidelines[4] must be followed. More specifically, in order to ensure the accessibility of authoring tools like LMS or LCMSs, WAI Web Content Accessibility Guidelines (WCAG) (W3C, 2008) and Authoring Tool Accessibility Guidelines (ATAG) (W3C, 2010 a) should be closely followed, as well.

The WCAG guidelines are the most important components of the WAI. They are considered the official standard in the European Union and are referenced in most legislation worldwide. Other important initiatives exist, as well, such as U.S. legislation (29 U.S. Code §794d) requiring conformance with U.S. Section 508 technical standards, some of which relate specifically to web accessibility. Although less extensive, these standards are nevertheless quite similar to the WCAG and studies exist in the accessibility literature that map the section 508 with the WCAG. While most current regulatory frameworks still reference the WCAG version 1.0, in December 2008 the WCAG 2.0 was published as a new W3C Recommendation.

According to the W3C, the ATAG Recommendation is the method for evaluating accessibility requirements in LMS. The ATAG directs web designers and developers in producing accessible output (*i.e.*, web pages) that meets standards and guidelines. Moreover, they provide guidance for prompting the content author (*i.e.*, the authoring tool user) for accessibility related information. Furthermore, they provide ways of checking and correcting inaccessible content, and integrating accessibility into the overall "look and feel" of the final software. Finally, these guidelines provide help and documentation to make the authoring tool itself accessible for people with disabilities. While the version ATAG 2.0 is has been developed (as a working draft) to be compatible with WCAG 2.0, ATAG 1.0 continues to be the current W3C Recommendation. According to ATAG 2.0, the LCMS user interface should be accessible and, at the same time, support the production of accessible content as specified in WCAG. We use ATAG 2.0 in sections three and four of this study.

Accessibility Metadata and Models

Considering adaptability as an additional resource of accessibility, some learning platforms are based on the use of metadata, such as that of the Dublin Core Adaptability Statement and IMS Global Learning Consortium[5]. With respect to this adaptability approach, the most important educational standards are ISO/IEC JTC1/SC36/WG7 "Access for All" and the IMS AccessForAll Metadata Specification (AccMD)[6].

User-Centered Design

The user-centered design (UCD) approach is a process in which the needs and preferences of end-users of a product are taken into account when that product is designed. The approach is particularly useful to consider in evaluations of the accessibility of LMS, and its inclusion in the evaluation process is given methodological support by standards such as ISO 9241-210:2010 (which replaced ISO 13407:1999)[7] . In order to fully consider the access-specific characteristics of persons with disabilities and the diverse contexts of use that may create barriers to web accessibility (Newell, AF. & Gregor, P., 2000), the UCD approach may be further extended to that of Inclusive Design (Henry, S. 2007). The WAI indicates following this approach in the accessibility evaluation process (W3C, 2010 c).

The evaluation process presented in this chapter uses this approach, promoting the participation of end-users with disabilities as well as accessibility experts.

Assistive Technology

Disabled users interact with computers through Assistive Technologies (ATs) and, as mentioned earlier, it is essential to take ATs into account when the UCD approach is followed in the evaluation process. Many different types of ATs exist to respond to the diversity of needs of users with disabilities. An example of an AT for users with vision impairment is a screen reader which describes in audio the visible information appearing on a computer screen. For blind users, some specific User Interface (UI) features are required, such as providing a full control of interface elements, as well as easy and rapid navigation via keyboard. If web sites are designed in accordance with WAI Guidelines, the accessibility requirements for ATs will be included. In such cases, therefore, ATs should successfully interpret and relay back to the user the semantic mark-up included in the web pages with WAI-ARIA (W3C, 2010 d).

The case study presented later in this chapter considers an LMS accessed with a screen reader. Screen readers, such as JAWS[8] or Window-Eyes[9], are commercial, special-purpose software programs. The Linux Screen Reader[10], the Orca screen reader[11] for the GNOME platform and the NVDA screen reader for Windows[12] are free alternatives to these commercial products. Additionally, Fire Vox[13] is a free extension to the Firefox web browser that provides screen reading functionality, the HearSay web browser[14] is a standalone self-voicing web browser, and aiBrowser[15] is a self-voicing web browser attempting to make multimedia web content accessible to blind users. Nevertheless, due to the expense of commercial screen readers and the general lack of knowledge in the non-visually-impaired community about their importance or the availability of free alternatives, screen readers are seldom installed on computers not normally and predominantly used by blind individuals.

For the evaluation presented later in this study, a JAWS screen reader was used. JAWS is a screen reader which is able to recite aloud almost everything encountered on a web screen. It is compatible with the Microsoft Windows operating system and IBM Lotus Symphony. It uses an adjustable synthetic voice to give feedback in the form of aural translations of user keyboard commands, as well as of text/graphics depicted on the Internet. Any text, graphics or links are automatically recited by JAWS at variable speeds and volumes. JAWS was chosen here due to its wide use, configuration options according to the needs and preferences of each user, and versatility in achieving better functioning and monitoring of various applications.

LMS AND ACCESSIBILITY

LMS Accessibility Studies

Some LMS or LCMSs such as Moodle, dotLRN[16] or Atutor[17], are designed with consideration for accessibility standards and problems. Most often, such systems are based on learning standards like SCORM and IMS and on accessibility standards like ATAG and WCAG. Moreover, some important initiatives carried out in the area of accessibility and online learning systems have also been developed (Martin, L et al, 2007), (Iglesias, A. et al, 2009). Other LCMSs found in the literature include Dokeos[18], Docebo[19], Sakai[20], and Blackboard[21].

For the evaluation of the accessibility of an LMS presented in section four below, Moodle was chosen due to the fact that it is one of the most widely-used LMS in the world (the Moodle.org website indicates that there are currently over 49,000 registered Moodle sites in 210 countries with over 34 million total users). Developed at the Open University of the United Kingdom which includes close to 9,300 individuals with disabilities among the total number of students

enrolled, Moodle is an open-source, flexible software focused on providing accessibility to all users. The software offers a large spectrum of available tools including, but not limited to, course resources, assignment modules, blogs, chats, forums, glossaries, interaction, SCORM packages, surveys, quiz modules, and wikis.

Due to the complexity of LMS, very few accessibility evaluations have been conducted to date. Of the evaluations conducted, however, the problems identified were often similar to those of static web sites. These problems are compounded by a poor navigational structure, color contrast problems and other significant problems related to a mark-up which conflicts with user agents and ATs.

Furthermore, only a few studies have been undertaken to determine the general types of accessibility barriers common to most LMS and considered as authoring tools. Most of these studies present the following two particular drawbacks. First, since the majority of these studies are based on survey and interview data rather than on empirical results, it has been difficult to make a convincing case at institutions of higher learning for improved accessibility awareness, training and procedures. Second, while all of the studies found present evaluations with respect to the WCAG, none do the same with respect to the ATAG.

Regarding particular studies, in Kalnins-Cole & Peters (Kalnins-Cole, T. & Peters, D., 2007) an evaluation of dotLRN is presented along with recommendations for development changes that would make dotLRN compliant with the W3C international accessibility standards. Results from the study show that dotLRN nearly possesses Level A compliance (according to the international standards) and that full Level A compliance would be easy to achieve. The study identifies Level AAA compliance as a desirable long-term goal.

In Power et al. (Power, C. et al., 2010), an initial empirical investigation into accessibility problems present in three different virtual learning environments – Moodle, dotLRN and Blackboard – is conducted. Nevertheless, the study is rather limited in that it only takes into account some examples of web pages and only evaluates a small subset of Moodle tasks with respect to an equally small subset of WCAG 1.0 checkpoints. In Santos et al. (Santos, O.C. et al, 2007), results obtained in the study of an e-learning framework with an initial end-user evaluation are presented.

Additionally, very few studies exist in the literature that consider the use of screen readers by the visually-impaired. In (Buzzi C. et al, 2009), the compliance of Moodle software with WCAG 1.0 and the use of WAI-ARIA Suite is evaluated; however, and as in Power et al., only a small subset of Moodle tasks is taken into account. Finally, the study does not check for Moodle's compliance with the ATAG.

To our knowledge, no evaluation studies of the accessibility of LMS or LCMSs exist using the ATAG. This paper tries to address the limitations of previous studies, therefore, by presenting an evaluation process for the Moodle LCMS as accessed with a JAWS screen reader. Moreover, the study is based on accessibility criteria in instructional design and universal design principles (Elias, T., 2010).

LMS Accessibility Evaluation Methodology

The ATAG offer a resource for evaluating the extent to which accessibility requirements are met by authoring tools. An LMS or LCMS is an authoring tool for building educational software, so ATAG should be taken into account if the software is to be accessible to all students.

As discussed in the prior sub-section, while a number of studies of evaluation methodologies for the WCAG can be found in the literature and the WAI, such is not the case with the ATAG. To our

knowledge, a formal evaluation methodology for authoring tools needs to be proposed. It is the main aim of the present paper: to offer a new proposal of accessibility evaluation methodology for LMS.

The new proposal presented in this paper extrapolates the WCAG evaluation methodology from WAI (W3C, 2010 c) to be applied while taking into account the ATAG guidelines. It is important to note that ATAG 2.0 includes testable success criteria, techniques, and references to WCAG 2.0, so such an extrapolation is possible.

While software tools exist that allow for the automatic checking of the WCAG conformance level, no such tools are available for the ATAG. Even with the existing tools, however, there are many aspects of accessibility that can only be evaluated manually. Thus, the combination of manual and automatic methods, together with end-user testing following the UCD approach, guarantees the detection of barriers to accessibility as well as the later implementation of more effective accessibility solutions.

In general, three types of accessibility testing techniques exist (Abou-Zahra, S. 2008) which obtain the best results when combined in such a way that capitalizes on the specific advantages of each. These three techniques are the following:

- **Automated Testing.** This technique is carried out by software tools without the need for human intervention. In automated testing, the syntactic structure of web content is analyzed (*e.g.*, checking for alt attributes in <img> HTML elements). The testing technique is quite cost-effective. However, an important drawback is that it only addresses a subset of the accessibility provisions set out by most standards.
- **Manual Testing.** This technique is carried out by human evaluators who could be experts or novices, depending upon the nature of the accessibility test. In practice, most tests carried out by human evaluators are also frequently guided or supported by automated software tools. The principal advantage offered by manual testing is that it covers a broader range of accessibility provisions than that considered by automated testing. For example, manual testing can check if the alt attribute accurately describes the purpose of its corresponding image or contains typical default texts such as ‘‘image’’.
- **End-User Testing.** This technique is carried out by real-world end-users. Logically, the technique focuses on the end-users and how well specific technical solutions match their needs in a specific context. This testing technique easily complements the other techniques previously described.

The goal of accessibility standards is to isolate accessibility problems and to define provisions for avoiding them. Some accessibility provisions, but not all, can be detected by using automated testing. Moreover, it is important to identify the underlying causes of an accessibility problem. Sometimes accessibility problems exist with web content, but other times they originate with the browser, ATs or even the user’s inability to handle the tool.

With the use of these different techniques, a particular method for the evaluation of authoring tools as LMS is proposed and described in the following section.

Accessibility Evaluation Method for Lms

This chapter presents a new method of LMS evaluation based on WAI recommendations. Following the consideration of the many different existing techniques for manual and automated testing, it was concluded that a modified version of the WCAG evaluation process would be most appropriate here. This modified evaluation method includes the following steps and elements:

- Set the ATAG 2.0 conformance level for which the evaluation is to be carried out.
- Identify web pages and tasks to be selected in the evaluation process, checking the main functionalities and contents of the LMS with manual testing by people most likely to enter the site. In LMS, these people can be classified into three groups or profiles: administrator, teacher and student.
- Combine and apply the distinct evaluation methods listed below and described in greater detail in the following sub-sections:
  - ATAG Expert Evaluation Method (with automatic and manual testing)
  - Expert Evaluation Testing
  - End-User Testing
- Draw conclusions with a discussion of the types of problems encountered, as well as the best practices to be continued or extended. Indicate the method used to identify the problems discussed and finally, to recommend follow-up steps to be taken for every accessibility barrier found during the process (e.g., markup validation and other tests). This would help to test for full conformance and address any problem identified previously.

ATAG Expert Evaluation Method

The method demonstrates compliance with the ATAG 2.0 Working Draft and the WCAG 2.0 Recommendation. The method comprises automated and manual tests, the latter of which being supported by automatic tools. The steps of the method are as follows:

- **Automated evaluation.** Use two general accessibility evaluation tools at least and note any problems indicated by the tools. These tools only exist for checking the WCAG.
- **Manual evaluation.** Complete the following steps:
  - Examine a selection of web pages using ATAG 2.0. As an additional resource for the checklist offered in the official documentation for the ATAG, this chapter has defined agile guides for the application of the ATAG, which are described in greater detail in the following section.
  - Use several user agents to browse and check the following:
    - Turn off images and check whether the appropriate alternative text is available.
    - Turn off the sound and check that the audio content is still available through text equivalents.
    - Use the browser controls to vary font-size, checking that the font size changes on the screen accordingly and that the page is still usable with larger font sizes.
    - Test with different screen resolutions (i.e., by setting the application window to less than the largest available size) in order to check that horizontal scrolling is not required.
    - Change the display color to grayscale and check whether the color contrast is adequate.
    - Unplug the mouse and check that all links and form controls can be accessed by tabbing through them. Additionally, check that the links clearly indicate what they lead to.
    - Read over the pages and check whether the text is clear and simple.

- Use a text browser (e.g., Lynx) and check if the information available through the GUI and text browsers is the same. Also, check if the information in the text browser is presented in a meaningful order if read serially.
- Summarize the results.

As discussed in previous sections of this chapter, the ATAG establish the accessibility guidelines for the design of web content authoring tools. These guidelines are organized into two parts which specify the following: (1) the authoring tool should be accessible and usable for authors with disabilities and (2) the authoring tool should permit, support, promote and guarantee the production of accessible web content. Similar to the WCAG, the ATAG establish three different levels of conformance: Level A, Level AA and Level AAA.

For the elaboration of agile guides for accessibility evaluation process, an analysis of official documentation for the ATAG was carried out. Results revealed that the application of the guidelines in the order given in the documentation was quite heavy-handed. The evaluation process was quite long and tedious and required the repetition of particular tasks at distinct moments. The performance of these tasks could be easily improved, with the definition of concrete application paths and guidelines.

Using the Working Draft of July 8th, 2010 (W3C, 2010 a) an agile guide for the ATAG was elaborated and is presented below in Table 1. As can be observed, each of the different groups presented are applied sequentially.

The process described above has been created to optimize and make more agile the accessibility evaluation process of authoring tools. Relative to evaluations carried out prior to those discussed in this chapter, the application of these agile guides resulted in a considerable reduction in evaluation times and a greater understanding of the guidelines.

Expert Evaluation Testing

The method includes manual testing carried out by evaluators (1) with intimate knowledge of how people with disabilities use the web and (2) who

Table 1. Agile guidelines to evaluate ATAG 2.0

GROUP	DESCRIPTION	SPECIFIC GUIDELINES (ATAG)
Part A: *Make the authoring tool accessible for the user interface.*		
Group #1: *Content accessibility guidelines*	Necessary for the evaluation of conformity with the WCAG. The first guidelines to be followed if the LMS authoring tool is to be accessible.	A.1.1.1, A.3.1.2, A.3.2.1, A.3.2.2, A.3.3.1, A.4.1.1, A.4.1.2, A.1.1.2, A.3.1.3, A.4.1.3, A.1.1.3, A.3.1.4
Group #2: *Accessibility standards: Clients*	Guidelines corresponding to the evaluation of accessibility requirements concerning the authoring tool user interface	A.2.1.1, A.3.1.1
Group #3: *Accessibility standards: Non-web tools*	Guidelines corresponding to the evaluation of accessibility requirements for non-web tools.	A.1.2.1, A.2.2.2, A.2.2.3, A.2.2.1
Group #4: *Accessibility in configuration & structure*	Guidelines corresponding to the evaluation of accessibility requirements regarding the configuration and structure of the tool.	A.2.3.1, A.3.2.2, A.3.2.3, A.3.4.1, A.3.4.2, A.3.4.3, A.3.4.4, A.3.5, A.3.6.1, A.3.6.3, A.3.6.3, A.3.7.2, A.3.7.1
Group #5: *Documentation accessibility*	Guidelines related to accessibility documentation facilitated by authoring tool.	A.4.2.1, A.4.2.2
Part B:*Support the production of accessible content*.		
Group #6: *Production of accessible content*	The same ATAG 2.0 guidelines are included and sequentially applied to groups with attention paid to the conformity level divisions A, AA and AAA.	

can accurately identify problems related to user interaction. Similar to walkthroughs and heuristic evaluations in the field of usability engineering, expert evaluators anticipate the issues that end-users may encounter in the content. In this method, manual evaluation is conducted using simulation (*e.g.*, testing keyboard access, the same view in several user agents) and screening techniques (*e.g.*, testing accessibility using a screen reader).

End-User Testing

Testing here is carried out by real-world end-users. It includes the evaluation of accessibility with ATs (W3C, 2010 b). User testing distinguishes between formal and informal checks, with the former usually being carried out by professionals following well-established procedures (surveys, interviews …) and the latter by non-experts.

In the following section, the method outlined here is used in a practical example of LMS accessibility evaluation.

CASE STUDY: EVALUATION OF ACCESSIBILITY IN MOODLE LMS

This section presents the method and the results obtained from an evaluation of the accessibility of the Moodle LMS. The evaluation of the LMS is performed with respect to the ATAG and the use of the JAWS screen reader AT resource.

Following the method described in the previous section, sub-section 4.1 examines the evaluation method using the ATAG, while the sub-section 4.2 presents an expert evaluation and user testing using both JAWS resource and combining the results in order to obtain tighten conclusions. In this case, the combined results improve the conclusions due to the fact that the problems and difficulties founded by end-users and experts accessing a product via an AT are not the same.. For example, end-users accessing an LMS via JAWS, due to their experience using non-accessible web-sites and using shortcut keys, are able to avoid accessibility barriers identified by accessibility experts. Additionally, accessibility experts may discover particular accessibility barriers previously passed over unnoticed by end-users due to the latter's extensive experience with screen reader software.

Evaluation Method: Checking Compliance with ATAG 2.0

In this sub-section, the main results obtained following the execution of the evaluation method are presented. The evaluation of the compliance of the Moodle LMS with ATAG 2.0 presented here was performed by two accessibility experts supported by the automatic tools TAW[22], AChecker[23], and the Web Accessibility Toolbar (AIS for Internet Explorer[24] and the Web Developer extension for Firefox[25]). In the evaluation, a direct installation of the official Moodle version 1.9 packages was made, and all basic web pages resulting from the installation were analyzed. While the inclusion of all possible content in Moodle web pages was not tested here, some different types were included and tested in order to verify Moodle's ability to create accessible content (Part B of the ATAG). A more detailed description of this evaluation is presented below.

In Part A of ATAG 2.0 Working Draft, all success criteria must present authoring tool user interface-related accessibility problems, this main that the authoring tool user interface must conform to WCAG. In Part B, all success criteria must present accessible web content production issues.

The result obtained in the accessibility evaluation of Moodle indicates that the lower accessibility level "A" of ATAG is not achieved. In relation to the evaluation of compliance of Moodle with WCAG 2.0, if Conformance Level "A" is obtained, then the success criteria A.1.1.1 of ATAG is fulfilled, but the A.1.1.2 and A.1.13 are not. Figure 1 and Figure 2 show the several levels of conformance resulting from the evaluation of Moodle with respect to ATAG 2.0 and WCAG 2.0

Figure 1. Number of ATAG (Part A and B) guidelines: fulfilled (Yes), did not fulfill (No) and did not apply (N/A)

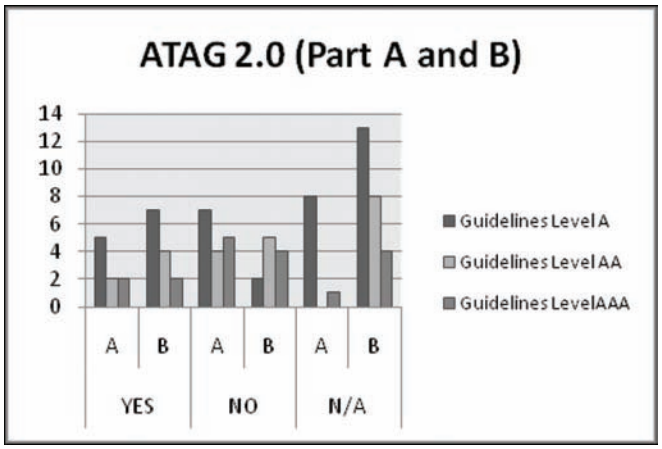
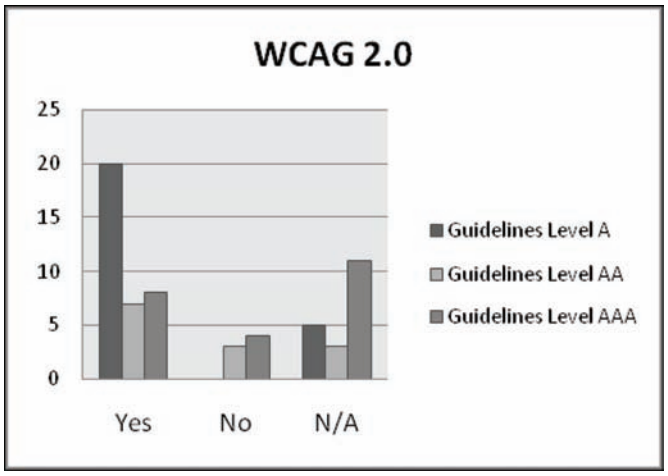


Figure 2. Number of WCAG guidelines: fulfilled (Yes), did not fulfill (No) and did not apply (N/A)



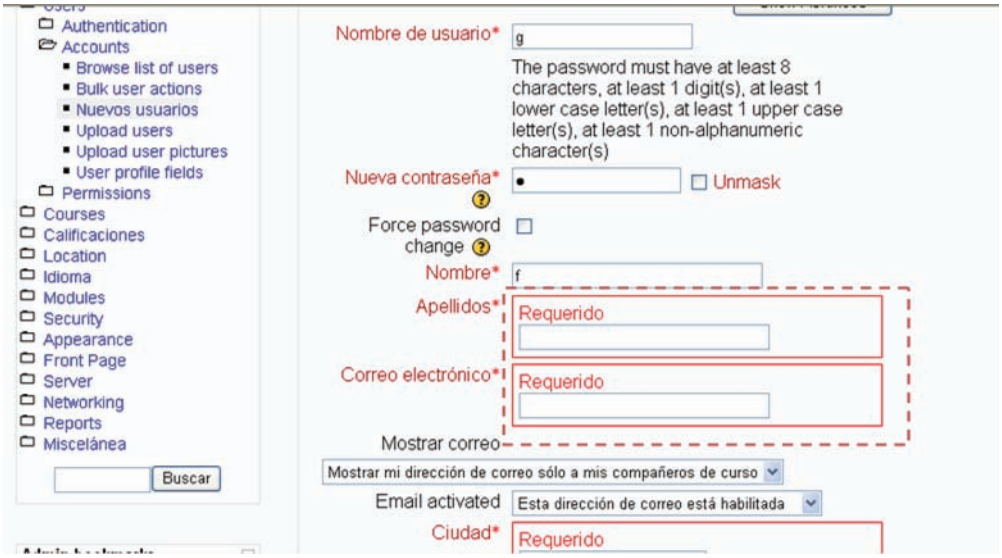
One feature obtained of evaluation of the compliance of Moodle with WCAG 2.0 is that in the user interface of the Moodle authoring tool for non-text content present to the user, Moodle shows an alternative text that serves the same purpose (Success Criteria 1.1.1. WCAG 2.0 [Level A) is fulfilled).

The functionality of the Moodle interface is operable through a keyboard (Success Criteria 2.2.1 of WCAG 2.0 [Level A] is fulfilled and Success Criteria 3.3.1 of ATAG 2.0 [Level A] is fulfilled too).

It is important to emphasize that Moodle in the assistant form with the help of users is able to avoid and correct mistakes. If an input error is automatically detected, the presenting the accessibility error is identified and then the error is described to the user in text as shown in Figure 3.

In the same way, labels or instructions are provided when content requires user input (Success Criteria 3.3.1 and 3.3.2 of WCAG 2.0 [Level A] is fulfilled). However, if an input error is automatically detected and suggestions for correction are known, the suggestions are not

Figure 3. Assistance in Moodle interface for forms: Help users correct mistakes



provided to the user (Success Criteria 3.3.3 of WCAG 2.0 [Level AA] is not met).

Moodle uses tables for the layout for the main content of the web page. However, the content is understandable when it is read line to line, so there are no accessibility problems in this case. Additionally, there is a mechanism to bypass blocks of content that are repeated on multiple web pages (see Figure 4 the link: "Skip to main content").

The most important accessibility barrier found during the accessibility evaluation of Moodle's taking into account ATAG 2.0 is the failure to meet Guideline B.2.5: "Assist authors with accessible templates and other pre-authored content (Level AA)". Moodle offers multiple types of themes (*i.e.*, templates) to assign, but it does not provide a default theme with an accessible interface in compliance with WCAG 2.0 Level AA. Therefore, B.2.5.8 is not fulfilled. Additionally, Moodle does not provide support for creating accessible web content. Therefore some guidelines of Part B of ATAG 2.0 are not fulfilled.

Moodle provides a default WYSIWYG editor. The main problem found in the default editor used by Moodle is that the colors and fonts are included in HTML with the <font> HTML element, rather than by using CSS styles. Consequently, some WCAG 2.0 guidelines are not fulfilled. Additionally, if a user wants to add an image, the editor allows the user to include an alternative description which satisfies point 1.1.1 (Level A) of WCAG 2.0. Nevertheless, Moodle does not provide warning advices if the user does not include an alternative description for the image. Moodle does not prevent the user from making accessibility errors, so it does not satisfy the B.2.2 and B.2.3 guidelines from ATAG 2.0.

Other observed feature is about "lang" HTML attribute, Moodle WYSIWYG editor include it indicating the language of the system's contents. Nevertheless, Moodle incorrectly uses the <blockquote> HTML element, using it with the sole intention of achieving a visual effect and not for the real aim of the tag, which is to identify a text block as a quote. It does not comply with the 3.1.2 (Level AA) success criteria of WCAG 2.0.

One of the most important problems related to the use of JavaScript in Moodle is that when it is disabled in the user agent, it is not possible to use the WYSIWYG editor. As an alternative, Moodle gives a text area to edit the content. However, although a text area for plain text is an alternative

Figure 4. Mechanism in Moodle to bypass blocks of content that are repeated on multiple web pages

for editing contents, users usually make mistakes due to their lack of knowledge of accessibility guidelines resulting in an editing process which may not be accessible (2.3.3 of ATAG cannot be fulfilled). For instance, by disabling the use of its default editor, Moodle permits one to choose the background color of the editor's text area, an interesting option if it were necessary to achieve an ideal contrast of colors.

In the present evaluation, Moodle demonstrates only partial accessibility and does not comply with the WCAG or ATAG. Accessibility strategies must, therefore, be included in the design of future versions in order to obtain an LMS that is more accessible for all users.

Expert Evaluation and User Testing

The evaluation of the accessibility of Moodle was performed in July of 2010 by an accessibility expert. End-user testing was conducted by a visually-impaired person (since childhood) and habitual user of JAWS. Both the expert and end-user made a direct installation from official Moodle packages. Moodle 1.9 and JAWS 10.0 versions were used here.

A testing procedure with a list of tasks was completed in the evaluation process, checking the main functionalities and contents of Moodle. Both end-users and the accessibility expert interacted with Moodle – with the expert checking the list of tasks with and without JAWS – and in the same manner so that interaction results across the LMS would be comparable.

Appendix 1 shows a table (Table 2) with the tasks evaluated in column 3. This table presents the type(s) (*i.e.*, profile) of user with the ability to execute the task (*e.g.*, administrator [A], teacher [T], student [S]). With regard to this final category, while all these tasks can be performed by a Moodle user with an administrator profile, users with teacher or student profiles may execute only a subset of tasks. In the evaluation of accessibility, the complete set of Moodle functionalities comprising the tasks that every user can perform was checked. Also, this table shows the functionality group in other column and the name of the task evaluated in another column. The fourth column offers brief descriptions of accessibility problems

where they arose. And finally, the last column shows if the individual tasks could be executed using JAWS and, in affirmative cases, whether such executions involved accessibility problems (Yes*) or no accessibility problems (Yes). In cases where accessibility problems using JAWS prevented the successful execution of the task, a different symbol (No) is used. As opposed to the related work previously described, the accessibility analysis presented in this study was performed on all basic web pages resulting from the direct installation of Moodle technology. This allowed us to assess Moodle's full capacity for accessibility for visually-impaired users.

As was briefly discussed earlier in the study, there is sometimes an overlap between barriers to accessibility and usability problems (Moreno, L. et al, 2009), entailing cognitive barriers to the successful use of the virtual learning environment. Some major usability problems directly affecting accessibility have been detected here and have been included in Table 2 together with accessibility barriers.

Following the exhaustive evaluation process, it is quite clear that the combination of accessibility expert and end-user evaluation is extremely helpful for the detection of the principal accessibility problems present in Moodle. Furthermore, many of these accessibility problems such as the lack of descriptive tags and section headings for web pages and forms, the dependency upon the non-accessible Windows editor for long strings in the forms (*e.g.*, descriptions), the changes to the look and feel of different tasks and the redirection to other web page or the refreshing of web page without previously notifying the user are repeated in multiple Moodle tasks. In sum, the errors detected are those presented below:

- E1: Not all text and combo boxes contain associated descriptive texts.
- E2: Pages refresh without previously consulting the user.
- E3: The user is redirected to another page without prior warning.
- E4: The look and feel of Moodle changes in some tasks.
- E5: Tables are used for layout.
- E6: Text images are used to convey information.
- E7: Information regarding how to complete a task is confusing for the user or difficult to obtain.
- E8: Some text in English appears even when Spanish is the selected language of the tool.
- E9: There is no button allowing the user to cancel the operation.
- E10: Tables are not well structured, creating problems for the screen reader.
- E11: There are no page or table headings.
- E12: The many rows in the table make the table difficult to read and require the user to memorize the table structure.
- E13: Text appears that can only be modified with Windows tool and it do not access by keyboard.
- E14: Some text descriptions are incorrect.
- E15: The application does not check data inserted into the form, and the errors messages are not useful for the users, making it difficult for users to imagine the cause of particular problems.
- E16: The screen reader does not always read the text correctly.

Table 2 presents the detail of all these errors including the tasks were they are found.

As it can be observed, the tool contains many different obstacles to accessibility, the most commonly produced of which being E4 and E1. With these errors, the user may be confused since the appearance of the website is not always the same and the content is not always clear. The least frequently produced errors from the list are E12, E14, E15 and E16. Thus, while important, these errors

are nevertheless relatively insignificant insofar as they appear only once in the tool.

It is very important to understand that these accessibility problems can seriously and negatively affect any type of Moodle user (*i.e.*, administrators, teachers, and students), keeping the user from correctly and completely accessing the LMS.

CONCLUSION

Learning Management Systems (LMS) and Learning Content Management Systems (LCMS) are nowadays necessary in institutions of higher education and should be accessible for users with and without disabilities. For this reason, accessibility standards must be considered. In this chapter, technology and disability standards for LMS have been examined in detail. In order to fully develop and use a resource to evaluate one such system, the most important LMS-related standards such as ATAG and WCAG have been described. In addition, the UCD approach has been introduced and recommended in order to take into account the participation of users with disabilities in the LMS accessibility evaluation process.

In addition to the review of related literature, a new general method for evaluating the accessibility of an LMS based on automatic, expert and end-user testing has been proposed. The combination of several techniques has returned more complete result in this experimentation. With the objective of presenting a practical application of the method, a case study focusing on the Moodle LMS and visually-impaired end-users (*i.e.*, those requiring screen readers) has been carried out and analyzed.

The results obtained from the case study demonstrate that the Moodle LMS is only partially, not completely accessible. Moreover, the evaluation shows that an LMS or LCMS does not usually support the task of authoring, reusing or re-purposing contents as well as virtual spaces for student interaction. For instance, Moodle does not offer sufficient support to teachers, despite the fact that it is they who are ultimately responsible for the contents of the LMS and their accessibility. Therefore, it is very important to follow accessibility strategies in Moodle module sites. Lastly, this study has pinpointed specific contexts in which a particular user group cannot access certain features and contents of the LMS.

FUTURE RESEARCH

One of the most consistent problems with modern learning management systems is their failure to comply with international standards for accessibility. There is a clear need for fully accessible LMS to be made available, so that educational institutions can meet the needs of all students, including those with disabilities. Future LMS development should be required to meet specified levels of accessibility and future LMS research should define methodological frameworks to be used to achieve this accessible development. Furthermore, additional work must be done to develop accessibility policies that can be implemented by institutions of higher learning. In this way, not only may the needs of individuals with disabilities be completely addressed, but the greater university community may also be educated about these needs in the process.

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KEY TERMS AND DEFINITIONS

Assistive Technology: Software (or hardware), separate from the authoring tool, that provides functionality to meet the requirements of users with disabilities. Some authoring tools may also provide direct accessibility features

Authoring Tool: Any software, or collection of software components, that authors can use to create or modify web content for use by other people.

Template: A content pattern that is filled in by authors or the authoring tool to produce content for end users (e.g., document templates, content management templates, presentation themes). Often templates will pre-specify at least some authoring decisions.

User-Centered Design Process (UCD): "Human-Centred design is an approach to interactive system development that focuses specifically on making systems usable. It is a multi-disciplinary activity." In UCD, all "development proceeds with the user as the center of focus."

Web Accessibility: Web accessibility means that people with disabilities can use the Web. More specifically, Web accessibility means that people with disabilities can perceive, understand, navigate, and interact with the Web, and that they can contribute to the Web. Web accessibility also benefits others, including older people with changing abilities due to aging.

WYSIWYG: This is an acronym for "What You See Is What You Get". A WYSIWYG view displays (to authors) the content being edited in a way that is very similar to how it will appear to end users.

ENDNOTES

1 Moodle, a Learning Management System (LMS). Available at http://moodle.org/
2 IMS Global Learning Consortium. Available at http://www.imsglobal.org/
3 W3C: The World Wide Web Consortium. Available at http://www.w3.org/
4 WAI: Web Accessibility Initiative from W3C. Available at http://www.w3.org/WAI/
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APPENDIX 1: TABLE 2 WITH SUMMARY OF EXPERT AND USER EVALUATIONS

This table presents the type(s) (*i.e.*, profile) of user with the ability to execute the task (*e.g.*, administrator [A], teacher [T], student [S]), the functionality group, the name of the task evaluated. The fourth column offers brief descriptions of accessibility problems where they arose. And finally, the last column shows if the individual tasks could be executed using JAWS and, in affirmative cases, whether such executions involved accessibility problems (Yes*) or no accessibility problems (Yes). In cases where accessibility problems using JAWS prevented the successful execution of the task, a different symbol (No) is used.

Table 2. Summary of expert and user evaluations

User Profile	Functionality (group)	Task Name	Errors	Can it be completed?
A/T/ S	General	Login user	E1	Yes*
A/T/S	General	Change language Moodle	E1/E2	Yes*
A	Users/ Authentication	Manage authentication	E8 /E10	Yes*
A	Users/ Authentication	Email-based self-registration	E5	Yes*
A	Users/ Authentication	No login	E7	Yes*
A	Users/ Authentication	Manual accounts	E5	Yes*
A	Users/Accounts	Browse list of users	E7/E5/E9/E10	Yes*
A	Users/Accounts	Bulk user actions	E2/E11	Yes*
A	Users/Accounts	Add a new user	E6/E8/E11/E13	Yes*
A	Users/Accounts	Upload users	--	Yes
A	Users/Accounts	Upload user pictures	--	Yes
A	Users/Accounts	User profile fields	E3/E7/E13	Yes*
A	Users/Permissions	Define roles	E7/E8/E13	Yes*
A/T	Users/Permissions	Assign system roles	E1/E9	Yes*
A	Users/Permissions	User policies	E8/E9	Yes*
A/T*	Courses	Add /Edit courses	E4/E13	Yes*
A	Courses	Enrollments	E9/E11	Yes*
A/T/S	Courses	Participants	--	Yes
A/T	Courses	Backup	--	Yes
A/T	Courses	Restore a course	E5/E7/E9/ E10/E11	No
A/T	Courses	Import	E4/E5	Yes*
A/T	Courses	Reset course	E4	Yes*
A	Grades	My preferences grader report	E1/E3/E4/E6/ E7/E11	Yes*
A/T/S	Grades/View	Overview report	E1/E4	No
A/T	Grades/View	Grader report	E1/E4	Yes*
A/T/S	Grades/View	User report	E1/E4/E10	Yes*
A/T	Grades/Categories and Items	Simple view	E1/E4/E10	Yes*
A/T	Grades/Categories and Items	Full view	E1/E4/E8/E10/ E12	Yes*
A/T	Grades/Scales	View	E1/E4/E10/E13	Yes*
A/T	Grades/Letters	View	E1/E4/E16	Yes*
A/T	Grades/Letters	Edit	E1/E4	Yes*

continued on following page

Table 2. Continued

User Profile	Functionality (group)	Task Name	Errors	Can it be completed?
A/T	Grades/Import	CSV file	E1/E4/E9	Yes*
A/T	Grades/Import	XML file	E1/E4	Yes*
A/T	Grades/Export To	Open doc spreadsheet / Plain text file/Excel spdsht/ XML file	E1/E4/E9	Yes*
A/T	Reports	Filter logs	E1/E4	Yes*
A/T	Reports	Activity report	E4/ E14	Yes*
A/T	Reports	Participation report	E4/ E8/E11	Yes*
A/T	Questions	Questions bank	E3/E8/E13	Yes*
A/T	Reports	Live logs from the past hour	E2	No
A/T	Questions	Import	E4/E7	Yes*
A/T	Questions	Export	E4/E9	Yes*
A/T	Files	List of files	E1/E4/E7/E10/ E11	Yes*
A/T	Files	Upload a file	E3/E4/E8/E11	Yes*
A/T	Files	Make a folder	E1/E11/E15	Yes*
A/T	Groups	Create group	E4/E6/E11/E13	Yes*
A/T	Groups	Delete group	E4/E11	Yes*
A/T	Groups	Add/Remove users	E1/E4	Yes*
A/T/S	New event	New event	E11/E13	Yes*
A/T/S	Export calendar	Export calendar	E11	Yes*
A/T	Forums	Add / Edit a new topic	E1/E4/E11/E13	Yes*
A/T	Forums	Delete topic	E4	Yes*
A/T	Forums	Reply	E1/E3/E4/E11	Yes*
A/T/S	Profile	Change password	E4/E8/E11	Yes*
A/T/S	Profile	Edit profile	E4/E8/E11/E13	Yes*