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Towards Improving the Accessibility and Usability of a Mobile-based Learning Management System for Blind Primary School Teachers

Aron KONDORO[1,2], Salome MARO[1,2], Joel MTEBE[1,2], Jamie PROCTOR[2,3], Aneth KOMBA[5], Björn HAßLER[2,4]
[1]*University of Dar es Salaam, Dar es Salaam, P.O. Box 35091, Tanzania*
Email: awkondoro@gmail.com
[2]*EdTech Hub, Victoria, SW1H 0HW, England*
[3]*Foreign Commonwealth & Development Office, London, SW1A 2AH, United Kingdom*
[4]*OpenDevEd, United Kingdom*
[5]*Tanzania Institute of Education, Dar es Salaam, P.O. Box 35094, Tanzania*

Abstract: Learning management systems (LMS) have been widely adopted to deliver learning materials for blended and online courses. Nonetheless, most of these systems suffer from accessibility and usability flaws that prevent visually impaired users from using them effectively. Despite existing studies evaluating the accessibility and usability of LMSs, very few of them have been done with actual visually impaired users. This study assessed the accessibility and usability of the Moodle LMS with 15 visually impaired teachers from 3 schools in 3 regions in Tanzania. The study used the Axe Dev automated tool and Concurrent Think Aloud Protocol usability testing in two phases. Results show that despite efforts of LMSs such as Moodle to follow accessibility and usability guidelines, the system still has problems such as insufficient colour contrast, links with indiscernible text, meaningless alternative texts, and invisible gaps in the content. Furthermore, this accessibility and usability can only be detected while testing with real users. Therefore, we recommend putting more effort into real-world user testing before such a system can be deployed to visually impaired school teachers.

Keywords: Learning Management System; Visually impaired; Usability; Accessibility.

1. Introduction

Due to the proliferation of smartphones and Internet bandwidth technologies, many institutions in sub-Saharan Africa are increasingly adopting Learning Management Systems (LMS) for educational purposes. In Tanzania, the Tanzania Institute for Education (TIE) has recently adopted an LMS to implement its national school-based Teachers' Continuous Professional Development (TCPD) program. The program, organised in a decentralised model using schools and cluster-based Communities of Learning (CoL), aims to improve the teaching skills of primary school teachers. The program uses the Moodle LMS [1] to enhance the effectiveness and delivery of the TCPD model by allowing teachers to access teaching resources more conveniently from their own devices.

The TCPD LMS development involved several user-centred iterations, from user requirements generation to prototype development and implementation. During these different stages, the LMS was tested with potential users to obtain suggestions for improvement. Based on user feedback, two versions of the system were developed. The

first version was based on a mobile app teachers can download via Google Play and install on their mobile devices. The second version was designed as a web application accessible via web browsers.

During the design and development of the LMS, the user research team encountered many visually impaired teachers who also wanted to access the system. These teachers, however, struggled to interact with the system and access digital resources. This problem is because they have unique and different computer interactions than their able-bodied counterparts [2]. They require special assistive tools such as screen readers, screen magnifiers, text-to-speech engines, and alternative input devices that allow them to use the system independently. However, for these tools to work properly, they also require support from the LMS platform. For instance, the platform must support the configuration of alternative texts to images so that they can be read to visually impaired teachers.

Learning Management Systems such as Moodle have made significant progress to ensure that users with special needs can access and use the system. For instance, the latest version of Moodle already conforms to the standard Web Content Accessibility Guidelines (WCAG) 2.1 [2], [3]. Similarly, developers of mobile and smartphone platforms have also made significant progress in developing mobile assistive tools that allow users with special needs to interact with mobile devices [4]. The two biggest smartphone platforms, Android and iOS, have several accessibility features that visually impaired teachers can use to interact with the LMS [5], [6].

Despite the availability of accessibility features in LMSs and the progress with mobile assistive technologies, very few studies have been conducted to test these features with actual visually impaired users. For instance, Zdravkova et al. [7] explore and review the accessibility features of the major learning management systems. Even though the study shows how the LMSs have implemented these features, it does not assess them with real users. In another study, Nascimento et al. [8] developed an accessible LMS called AccessLearning with features allowing users with visual and hearing impairments to use the system. The study evaluated and tested the system with several students with special needs. However, even in this case, the evaluation process was limited to feedback via questionnaires that did not capture all aspects of the user experience. There is still a lack of real-world empirical data regarding the accessibility and usability of LMSs, especially in mobile environments.

Therefore, this study aims to evaluate the accessibility and usability of the mobile-based LMS with visually impaired teachers across three regions in Tanzania. The evaluation will help to identify and fix accessibility and usability flaws that could prevent visually impaired teachers from using the system more effectively and efficiently. The study fills an important knowledge gap in the literature by providing valuable empirical data regarding the accessibility and usability of the LMS from actual visually impaired users from the field. This contribution ensures the LMS serves the 456 visually impaired teachers in Tanzania's primary schools [9].

This study is organised into six sections. In section two, we discuss other related works that have been conducted concerning the usability and accessibility of LMSs. In section three, we describe the methodology used to evaluate the accessibility and usability features of the LMS. In section four, we describe and highlight the main findings from the study. In section five, we discuss the main implications of the results and provide recommendations for future improvements of the LMS. Finally, in section six, we conclude with key takeaways that can be deduced from the study.

2. Related works

Few studies have included blind or visually impaired users during the system evaluations. For instance, Babu and Singh [10] developed the task-oriented, user-centred, multi-method

evaluation technique to evaluate the accessibility and usability of LMS with blind and visually impaired students. This study found several accessibility and usability issues that affected users from using the system. Similarly, Buzzi et al. [11] conducted a study that found that Moodle LMS had accessibility issues, such as pages with too many links, images with no alternative text, and poor content structure. Power et al. [12] found serious accessibility problems, not per WCAG 1.0 accessibility guidelines amongst the Moodle, dotLRN8 and Blackboard systems. Iglesias et al. [13] evaluated the accessibility of three LMS: Moodle, Sakai and ATutor, as regards the compliance of each system with ATAG 2.0 and each system's user interface with WCAG 1.0. The usability focused on four parameters: templates and themes, content editor, Javascript and tables for layout. In general, the three systems had problems that would likely limit their accessibility for certain groups of users. Zdravkova et al. [7] also explored and compared the accessibility features of the major LMSs. The study concluded that despite the availability of these features, they are still not a substitute for physical learning, especially for blind users. Due to issues in existing platforms, other studies, such as Nascimento et al. [8], have developed a custom LMS to be more accessible to visually impaired users. The system was tested by several users who found it easier than conventional systems.

3. Methodology

3.1 Study design

The study was executed in two phases. In the first phase, we used Axe Dev Tools to assess the LMS's compliance with accessibility standards and guidelines. Axe Dev Tools is a set of developer tools that automates accessibility testing. The tool scans web pages and identifies areas where accessibility guidelines and standards are violated. The first phase was conducted in May 2022 and lasted for one week. The second phase involved user testing with teachers who were blind. The Concurrent Think Aloud Protocol (CTAP) was adopted involving 15 blind teachers from 3 schools in three regions in Tanzania (Tabora, Lindi, and Mwanza). The CTAP was complemented by a semi-structured interview conducted after the CTAP sessions.

3.2 Participants

A total of 15 teachers were involved in the study, three from Nyangao primary school in Lindi, four from Furaha Maalum primary school in Tabora and eight from Mitindo primary school in Mwanza. According to Lazar et al. (2017), a population of 5–10 users with a specific disability is acceptable for user research. Participants were recruited through a partnership with the President's Office – Regional Administration and Local Government (PO-RALG). All selected participants were blind, with at least five years of teaching experience, and either had a smartphone at the time of the study or had used a smartphone in the last three months.

3.3 The target system and sample

The TCPD Learning Management System was used as a target system for this study. In addition, the English Language course was used as a test course. The course consists of 7 units, each with a quiz of 5 questions. In addition, the course has a video in the introduction unit and images in various units.

3.4 Tasks

To evaluate the usability of the TCPD system, we formulated seven tasks to cover the process of creating an account, accessing the sample course, and conducting quizzes. The tasks were read out to the participant one after another during the user testing research. The set of tasks was as follows: 1) Access the LMS (we read out the link to the participant); 2)

Create a new user account, including completing the registration form; 3) log in to the system; 4) Find and access the English Language course; 5) Navigate from Unit 1 to Unit 7; 6) Play videos – listen to a video in the introduction unit; 7) Do a quiz for each unit from Unit 1 to Unit 7.

3.5 User testing procedure

At the beginning of the test, we introduced the study to the participants by reading out a prepared summary including the informed consent. Those who agreed to continue with the user research were given more instructions about the required tasks. The moderator read the link to the participants and asked them to access the system via a web browser. Those who did not have smartphones but had used them in the last three months were provided with smartphones. Since accessing the system required Internet connectivity, each participant received an Internet bundle.

During the CTAP session, participants were asked to think aloud while performing the tasks and pretend that the facilitators were not there. When doing so, they were asked to vocalise their thoughts and explain their actions by describing what they believe is happening, why they chose a particular action, and what they are trying to do while interacting with the system. They had to perform all the actions without asking for help from the facilitator. The facilitator also reminded them to keep thinking aloud if they were silent for a while.

The CTAP method requires participants to read aloud a task and prepare themselves for speaking out loud while performing the task later. As suggested by [10], we made minor modifications as this was impossible for blind users. The facilitator read the text for each task and explained what the participant was supposed to do.

Each CTAP session had two facilitators, with one moderating task and another recording issues encountered. Each participant was studied individually, and all sessions were video recorded. A total of 15 sessions were recorded across the three schools. After completing the tasks, we conducted a semi-structured interview which contained questions on three main aspects: (1) the participants' experiences on registering and using the system; (2) the participants' experience in accessing learning resources (e.g. video, quizzes, etc.) in the sample course; and (3) their overall perception on using the LMS for TCPD activities.

3.6 Data analysis

After the 15 CTAP sessions, we made verbal transcripts and noted all the participants' navigations through the system. Since all sessions were video recorded, the team could replay the videos to detect usability problems. The transcripts were analysed using a thematic analysis approach. We opted for inductive thematic analysis, where the codes emerged from the data, rather than deductive analysis, which starts with a predefined set of codes. This option made it possible to capture all aspects recorded in the data.

4. Results

4.1 Results from automated testing tools

The test scanned 12 web pages of the LMS. The scanned pages were the home page, signup page, login page and nine pages in the English Language course. In each unit, we scanned the landing page, a questionnaire page, and one quiz. The scanning tool identifies the type of issue and which rules or guidelines it violates, as well as categorises the accessibility issues found according to three impact levels (critical, serious and minor). Critical issues will make the system inaccessible by accessibility-specific technologies such as screen readers. Serious issues are issues that will cause frustration to users even though they can still use the system, while minor issues are issues that will cause small problems.

The tool identified 23 critical errors. On further analysis, all 23 issues were due to violation of "ARIA, WCAG 2.1 A,1.3.1 Info and Relationships", where custom-designed menu items were missing a role.

The serious issues found (88) were categorised as follows:

1. Colour contrast issues, where the LMS has insufficient colour contrast on most of the pages. This is because the LMS uses a grayscale colour scheme, which is not accessible to visually impaired individuals as the colour difference is not so noticeable.
2. Name, role value where some User Interface components were missing either a name, role or value/state. This makes it difficult for screen readers to tell the element's state. For instance, screen readers do not work well if a component does not define whether it is focusable or not.
3. Links, where some links did not contain discernible text and
4. Structural issues such as lists containing invalid children or regions that are not reachable because they are contained in other User Interface (UI) components.

Further analysis shows that colour contrast was the most serious (42 out of 116), followed by structural issues (23). The remaining ones can be described as UI elements missing a name, role, state or all of these. Additionally, these issues can be mapped to specific WCAG rules that were violated. Table 1 shows the distribution of the issues found according to type, quantity found and the specific rules violated.

Table 1: A mapping of issue type to the violated WCAG rule.

Issue type	Number of issues	Violated WCAG rule
Elements must have sufficient colour contrast	46	Color, WCAG 2.1 AA,1.4.3: Contrast (Minimum)
id attribute value must be unique	5	Parsing, WCAG 2.1 A,4.1.1 Parsing
Certain ARIA roles must contain particular children	23	ARIA, WCAG 2.1 A,1.3.1 Info and Relationships
Links must have discernible text	13	Name, Role, Value, WCAG 2.1 A,4.1.2 Name, Role, Value,2.4.4 Link Purpose, Section 508, Section 508 22 A, Accessibility Conformance Testing
Elements must only use allowed ARIA attributes	20	ARIA, WCAG 2.1 A,4.1.2 Name, Role, Value
and must only directly contain , <script> or <template> elements	12	Structure, WCAG 2.1 A,1.3.1 Info and Relationships
ARIA hidden element must not contain focusable elements	1	Name, Role, Value, WCAG 2.1 A,4.1.2 Name, Role, Value,1.3.1 Info and Relationships

4.2 User testing results

Before conducting the Concurrent Think Aloud Protocol usability testing, accessibility issues identified by the Axe Dev tool were fixed. The tool helps out by pointing to the location of each problem in the HTML files within the system. We used this information as a guide and manually reviewed all pages to correct the issues. This process took about one week and was worked on by two developers. Despite this effort, we still captured some accessibility issues at the end of usability testing. These issues are explained hereunder:

Invisible gaps

There are invisible gaps in the course's main content that hinder the screen readers' performance. For instance, the screen readers struggled to read the methodology section of Unit 1 due to the break in content. This break is invisible and is only detected when the screen readers are used.

Another issue found is that the inline frame is part of the page's main content, as shown in Figure 1. As a result, the screen readers try to read the frame contents. However, since it is empty, it appears as an invisible break in the main content that confuses users.

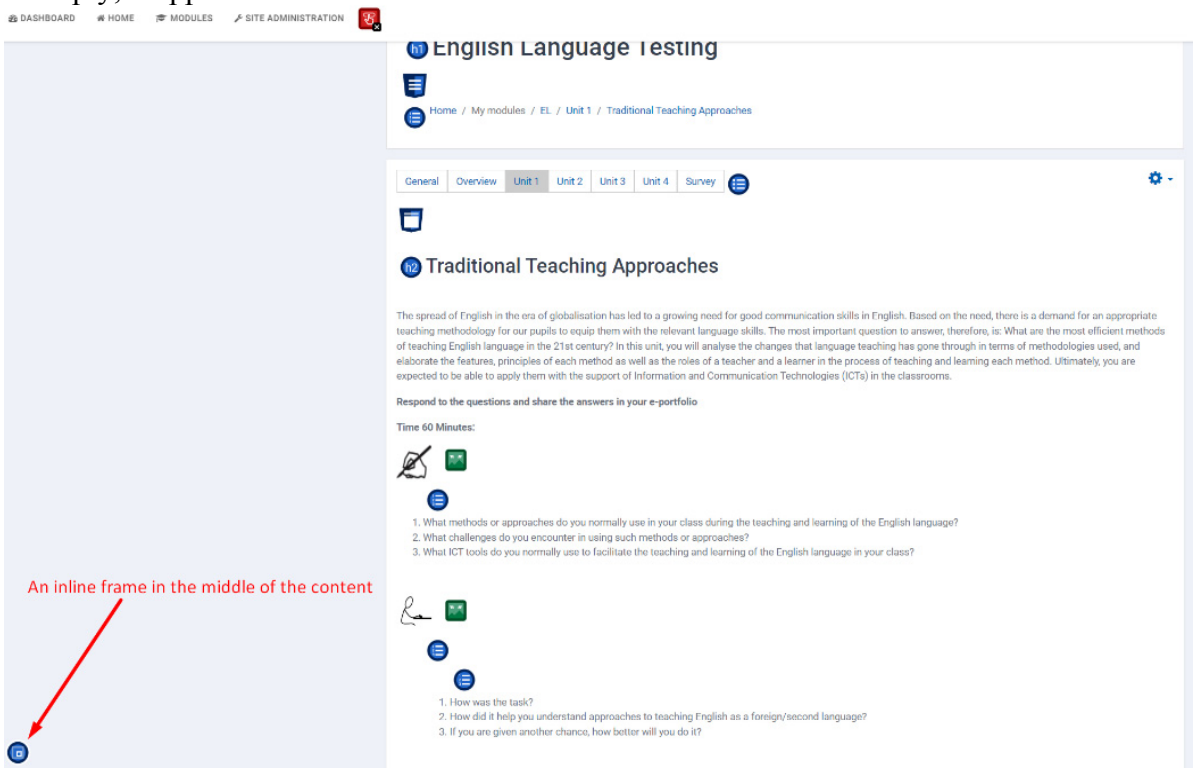

Figure 1. Invisible gaps detected during user testing research

Meaningless image alternative text.

Some images have alternative text that does not have semantics. For instance, several images had alternative texts with only numbers. While web accessibility tools can check that all images have alternative text, they cannot check if the text is semantically useful. This limitation means humans must manually test all course contents for accessibility issues.

Long dropdown menus

Some user interface components are not optimised for use with the accessibility features of smartphones. For instance, the dropdown menu for selecting regions and districts. When clicked, the dropdown displayed a pop-up with a list of regions as options, and teachers could not easily select on the phone. As a result, teachers struggled to complete the form and finish the registration process. In one case, the teacher failed to select the option from the dropdown, and the registration had to be completed on the facilitator's device.

LMS interface design issues

The main navigation is not optimised for teachers to move easily within the content. Most struggled to locate different sections and move from one part to another within the course. This problem was also observed when teachers were doing the quiz. It was difficult for them to navigate the different questions, and several occurrences of them being lost were observed. This problem was due to skipped heading levels and an invisible button with empty alternative text in the main navigation bar that interfered with the screen readers, as shown in Figure 2 and Figure 3. Another example is the popup tours, which are help dialogues displayed the first time a user accesses the system. The dialogue displays several

tour popups that the readers can randomly read. This issue caused teachers to be confused or distracted while trying to make sense of the content.

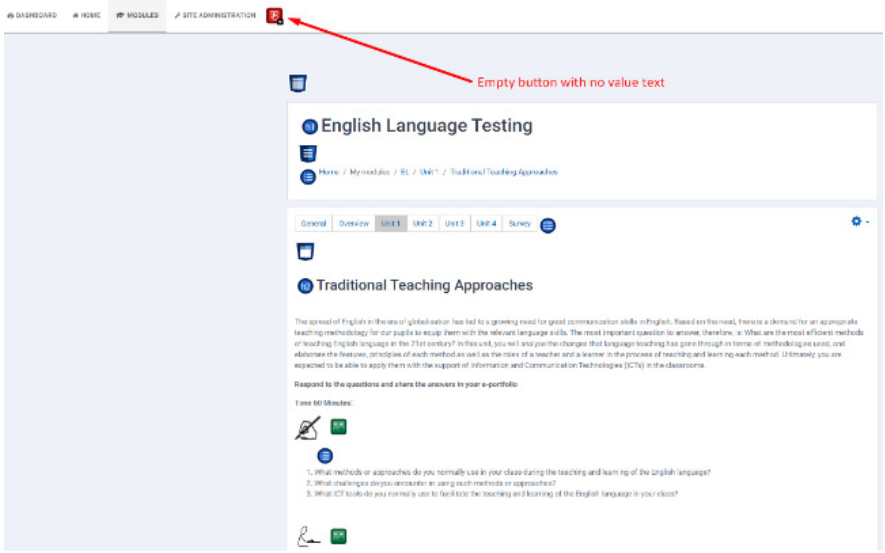

Figure 2. Some of the empty buttons with no value text

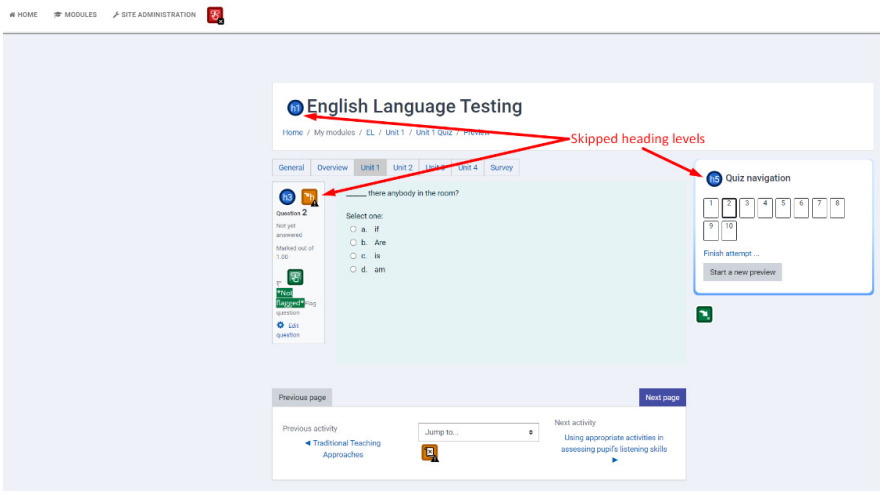

Figure 3. Some of the skipped headings

Content design issues

Long paragraphs: Some of the content in the sample course had long paragraphs which were read non-stop by the screen reader, making it difficult for the teachers to follow. Teacher A claimed: "there are long texts, and in some units, there are only 2-3 paragraphs. Such long content makes the screen reader read without pausing. For instance, unit 2 could be broken into small paragraphs so the screen reader can read and pause."

Design of multimedia content: It was found that most of the videos were recorded without considering that some visually impaired teachers cannot perceive visual cues. Teacher B indicated: "I was listening to the video in Unit 5, and the instructor said, as you can see here. Then I could not see what the instructor was showing, so I could not follow properly as I just noted I had missed something."

Quiz design: Most teachers struggled with the quiz due to the design of the quiz. For instance, for multiple choice questions, all answers are read twice by the screen readers. Additionally, there is no way to tell how many choices the question has until the teacher scrolls to the next question. Such issues make the quiz take too long. The quiz answers also contain aria-labelled attributes that facilitate use with screen readers. However, the attributes are not properly labelled and contain inaccessible text that confuses the screen

readers. Finally, the skipped levels of heading in the quiz pages interfered with the keyboard navigation and caused difficulties for users when they were trying to answer the quiz on their devices.

General usability issues

Locating URL: The URL (https://tcpd.tie.go.tz/) was complex for the teachers to type. Teachers took too long and made several mistakes while typing the URL since they had to navigate by touch and wait for audio feedback for each character. We observed that even though some teachers use smartphones, they only use them for phone calls meaning they are not accustomed to using apps such as the browser, and the concept of URLs was unclear to some of them.

On language: Android's default text-to-speech (TTS) engine does not fully support Swahili and struggles with proper pronunciation. To solve this, teachers recommended using audio recordings of the content instead of relying on the default TTS.

Length of the registration process: The registration process is too long and complex for visually impaired teachers. Since they have to rely on audio feedback, most of them took a long time to complete this process as there are many fields to fill out in the registration form.

5. Discussion

Using automated tools, the study found that the system had 23 critical errors, 88 serious issues, and five minor errors. Critical errors were attributed to poorly structured information and content not presented in more than one visual presentation to enable those with poor vision and blind users to access the system effectively. Most serious issues are related to colour contrast, missing components, links missing discernible text, and content structural issues. For instance, there was a problem with colour contrast on most pages as the system uses a grayscale colour scheme.

The presence of inline frames was an important accessibility flaw of the system. The system displayed the inline frame as part of the main content for all pages. These frames confuse blind users as they are empty. As suggested by [14], screen readers' feedback becomes ambiguous and confusing when pages have a complex layout.

The findings from CTAP identified usability flaws, including meaningless image alternative text, long dropdown menus, and some skipped headings. Other identified flaws include difficulties locating URLs, the registration process length, and poor pronunciations of the Swahili language. These issues were not discovered by using the automated Tool. This finding correlates with a similar study by [11], which found that icons and images without clear alternative descriptions make the LMS difficult for visually impaired users to use.

The study also found usability and accessibility barriers in the sample English course. These barriers include long paragraphs read non-stop by the screen reader, pop-up tours, and poor quiz design. This finding implies that the design of the learning resources should consider the limitations of visually impaired users. For instance, screen readers continuously read the content with long paragraphs, making it difficult for visually impaired teachers. In addition, content with long paragraphs causes screen-readers to mispronounce many words, which creates comprehension problems [15].

Similarly, poorly designed quizzes made question navigation difficult. Good page layout is an important aspect of the accessibility and usability issue as visually impaired teachers read through the page linearly (serially), one column at a time, one line at a time, and one word at a time [14]. Although the current LMS uses a default quiz layout, it must be customised considering these accessibility and usability issues.

Another usability problem was the inclusion of multimedia elements in the content. The sample English Language course has a video and several images within the content. However, with visually impaired teachers, two major problems arose. First, the lack of meaningful alternative text in most images and second, the videos were recorded without considering users who rely on audio. Therefore, care should be taken when multimedia elements are used in online courses.

LMS developers could easily address most of the problems reported in this study, and plenty of well-known automated tools can quickly fix the problems with a limited amount of technical skill. There is a lack of awareness of the impact of accessibility and usability issues on those involved in implementing blended and online courses [14]. We recommend putting more effort into assessing and testing LMSs in practice with visually impaired users before implementing these courses. This effort will help identify issues that cannot be easily detected by automated tools and ensure all aspects of the user experience are considered for successful deployment.

6. Conclusion

Majority of LMS is implemented without considering issues related to accessibility. Systems with accessibility and usability issues affect visually impaired users, which is becoming a big user group. This study provides two main contributions. First, the study confirms that automated tools cannot uncover all accessibility and usability flaws unless complemented with user research. Other issues, such as device capabilities, language compatibility, and content design, can only be identified with user research. Second, this study highlights the importance of evaluating the accessibility and usability of the system and the content in the field with actual visually impaired users using a think-aloud approach. So far, very few studies have adopted this approach. As a result, most findings fail to capture some aspects of the user experience and what goes through the minds of these users with special needs. Therefore, there needs to be more focus on performing more extensive assessments of LMSs using this approach to ensure that they are not only free of accessibility and usability problems but also that the content is suitable for visually impaired users.

References

[1] “Moodle - Open-source learning platform.” [Online]. Available: https://moodle.org/. [Accessed: Mar. 05, 2023]

[2] S. Chandrashekar and R. Benedyk, “Accessibility vs. Usability – Where is the Dividing Line?,” Contemporary Ergonomics 2006. pp. 231–235, 2020 [Online]. Available: http://dx.doi.org/10.1201/9781003072072-56

[3] J. Verdaguer, “The Moodle LMS achieves WCAG 2.1 AA Accessibility compliance,” Moodle, Dec. 02, 2020. [Online]. Available: https://moodle.com/news/moodle-wcag-2-1-aa-accessibility-compliance/. [Accessed: Mar. 05, 2023]

[4] A. Khan and S. Khusro, “An insight into smartphone-based assistive solutions for visually impaired and blind people: issues, challenges and opportunities,” Universal Access in the Information Society, vol. 20, no. 2. pp. 265–298, 2021 [Online]. Available: http://dx.doi.org/10.1007/s10209-020-00733-8

[5] C. Vendome, D. Solano, S. Linan, and M. Linares-Vasquez, “Can Everyone use my app? An Empirical Study on Accessibility in Android Apps,” in 2019 IEEE International Conference on Software Maintenance and Evolution (ICSME), Cleveland, OH, USA, Sep. 2019, doi: 10.1109/icsme.2019.00014 [Online]. Available: https://ieeexplore.ieee.org/document/8918937/

[6] R. Whitaker, Developing Inclusive Mobile Apps: Building Accessible Apps for iOS and Android. Apress, 2020.

[7] K. Zdravkova and V. Krasniqi, “Inclusive Higher Education during the Covid-19 Pandemic,” 2021 44th International Convention on Information, Communication and Electronic Technology (MIPRO). 2021 [Online]. Available: http://dx.doi.org/10.23919/mipro52101.2021.9596862

[8] M. Nascimento et al., “A learning management system accessible for visual, hearing and physical impairments,” in Lecture Notes in Computer Science, Cham: Springer International Publishing, 2019, pp. 481–493.
[9] “Singleministers.” [Online]. Available: https://www.tamisemi.go.tz/singleministers/basic-education-data-2022. [Accessed: Mar. 05, 2023]
[10] R. Babu and R. Singh, “Enhancing learning management systems utility for blind students: A task-oriented, user-centered, multi-method evaluation technique,” Journal of Information Technology Education: Research, vol. 12, no. 1, pp. 1–32, 2013.
[11] J. A. Jacko, Ed., Human-computer interaction. Interacting in various application domains: 13th international conference, HCI international 2009, San Diego, CA, USA, July 19-24, 2009, proceedings, part IV, 2009th ed. Berlin, Germany: Springer, 2009.
[12] C. Power, A. Freire, H. Petrie, and D. Swallow, “Guidelines are only half of the story,” in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Austin Texas USA, May 2012, doi: 10.1145/2207676.2207736 [Online]. Available: https://dl.acm.org/doi/10.1145/2207676.2207736
[13] A. Iglesias, L. Moreno, P. Martínez, and R. Calvo, “Evaluating the accessibility of three open-source learning content management systems: A comparative study,” Comput. Appl. Eng. Educ., vol. 22, no. 2, pp. 320–328, Jun. 2014.
[14] J. Lazar, A. Allen, J. Kleinman, and C. Malarkey, “What frustrates screen reader users on the web: A study of 100 blind users,” Int. J. Hum. Comput. Interact., vol. 22, no. 3, pp. 247–269, May 2007.
[15] M. F. Theofanos and J. (ginny) Redish, “Bridging the gap,” Interactions, vol. 10, no. 6, pp. 36–51, Nov. 2003.