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On the accessibility of Moodle 2 by visually impaired users, with a focus on mathematical content

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Abstract In this paper we study the accessibility by visually impaired people of the Learning Management System (LMS) Moodle 2. The study is conducted by testing four different visually impaired subjects, with different degrees of disability and performing different tasks connected to different roles in the LMS. A peculiar focus is given to the accessibility of content involving mathematics. At the end of the paper some recommendations to improve the accessibility of Moodle 2 are given.

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1 Introduction

Nowadays, e-learning platforms are becoming widely used educational tools to support teaching at any level of the education system. Accessibility is an important feature they should have and its evaluation has been studied by several authors as, e.g., in [7] and [13]. In particular, we recall the Eu4all project, cfr. [9], a European Commission-funded project about accessibility in higher education and lifelong learning. There are two main problems connected to the accessibility of e-learning platforms. The first, which in generally is not relevant for the evaluation of the accessibility itself, regards the accessibility of uploaded digital documents (e.g., pdf, docx, etc.). Some guidelines about this theme can be found in [3], [4] (focused on documents with mathematical contents) and [16]. The second concerns the accessibility of the platform itself and considers the tasks that a user has to deal with. For an assessment of the accessibility of various LMS the reader can refer to, e.g., [12] and [14].

Moodle is one of the most used e-learning platforms and for this reason the evaluation of its accessibility and inclusiveness is a very important task in order to guarantee the right to education. Hence, we propose a careful evaluation of Moodle's accessibility for visually impaired users. A detailed analysis of the accessibility of several tasks has been conducted with the aid of four visually impaired test participants. One of them is the fifth author of the paper (born blind) who performed tests simulating both the role of teacher and administrator on an Apple computer. The other participants

played the role of students using different operating systems (Windows 7, Windows 8, Mac OS X) and browsers (Internet Explorer 11, Mozilla 41, Safari 8). In fact, the accessibility of digital resources is affected by many factors (e.g. configurations of the browsers, operating systems, etc.). Thus, we conducted tests under several different conditions in order to highlight the criticalities strictly related to Moodle and not depending on other factors. The results of this evaluation show that Moodle as a whole is accessible to visually impaired people, since the participants were able to complete all the assigned activities. In particular, we would like to stress that the aim of this study is the accessibility of the LMS itself. The time to complete a task and the visually impaired user's satisfaction are different problems not addressed in the present work. However, some accessibility problems, which made some tasks in Moodle problematic, were encountered even if these problems were not severe enough to prevent each participant to fully perform a given task. Moreover, in this paper specific attention is given to the accessibility of mathematical contents since assistive technologies still have a long way to go as far as formulae are concerned. Indeed, these are usually represented in two dimensions, while assistive technologies can only manage one-dimensional structures like the natural language. Furthermore, an additional problem is given by the lack of an international standard braille code for mathematical symbols. Indeed, several countries have developed their own braille code for mathematics and a serious work in the direction of a unified braille system is far from being accomplished. For surveys on this topic, the reader can refer, e.g., to [15], [2] and [5].
The paper is structured as follows. In Section 2, the design of the accessibility evaluation is presented, focusing on the objective (Section 2.1), environment (Section 2.2), methods (Section 2.3), and participants (Section 2.4). Section 3 is devoted to the presentation of the results of the evaluation. Specifically, in Section 3.1 we present the error types that could affect a specific task, in Section 3.2 we describe the results, in Section 3.3 we focus on the accessibility of the mathematical content. In Section 4, some recommendations in order to improve the accessibility of Moodle are discussed. Finally, Section 5 is devoted to the conclusions.

2 Design of the evaluation

In this section we present the design of the accessibility evaluation, discussing the objective, environment, methods and participants. The object of this research is not a technical check of the standard guidelines of W3C: WAI-ARIA (Accessible Rich Internet Applications) 1.1, ATAG (Authoring Tool Accessibility Guidelines) 2.0 and WCAG (Web Content Accessibility Guidelines) 2.0. On the Moodle site there is a huge section about the accessibility stating that its development has followed the previous guidelines. However, there are some bugs and problems concerning the accessibility and developers are studying and solving them. For a technical check of WCAG 2.0, the VPAT (Voluntary Product Accessibility Template) Statement of Moodlerooms can be taken as a reference [1].

2.1 Objective

This research evaluates the accessibility of Moodle 2.7 from the point of view of visually impaired users, using screen readers and/or refreshable braille displays. The study evaluates accessibility from the point of view of users of all the three Moodle roles: administrator, teacher and student. The tasks were performed by different participants in the study, with different degrees of experience with the LMS: no experience for students and a basic introduction for teacher and administrator. This choice was performed to replicate the standard situation in a learning context: students should be able to use Moodle without previous experience; teachers and administrators, who are creators of new courses and the content therein, usually undergo a small training before being fully able to use the platform. It is important to notice here that our study analyses accessibility issues of the LMS itself, without considering problems of the user-generated content uploaded in it such as, for instance, .pdf files or images.

2.2 Environment

As the evaluation was conducted using Italian mother-tongue participants, this study focuses on the Italian language version of Moodle. However, since the problems that have been observed are not connected with the choice of the language, the study could have been conducted in any other language without effects on the results. To give a more complete evaluation, Moodle was tested with different OS and Web browsers (WB), namely:

- Mac OS X using Safari 8;
- Windows 7 using Internet Explorer 11;
- Windows 8 using Mozilla Firefox 41.

Different participants used different combinations of OS and Web browser, based on their usual habits of navigation and choice of screen reader. The combination for each participant is detailed in Section 2.4.

2.3 Methods

In order to conduct a proper evaluation, we chose a large amount of Moodle tasks, based on [10] and [11], which were identified as necessary for course management, students interaction with a teacher, and student fruitful interaction with the course content. These tasks were divided in categories, each category including one or more tasks, and the different participants tested each one of them in order to determine all the possible accessibility barriers. The categories were created with the following criteria:

- **General**: basic actions not related to a peculiar profile, which all the users of Moodle should be able to perform, such as login and logout;
- **Course**: actions related to interacting with a single course, such as editing a lecture;
- **Teacher**: actions related to interacting with a teacher, and thus related to the student's profile;
- **Student**: actions related to interacting with a student, and thus related to the teacher's profile;
- **Assignment**: actions related to managing the structure of an assignment;
- **Manager**: actions available only for the administrator's profile, such as creating a new course.

We limited ourselves to indicate the tasks and list all the accessibility issues that came over.

We would like to stress again that, in Moodle, individuals may interact with the LMS in three main different ways ("roles"):

1. Administrator (A);
2. Teacher (T);
3. Student (S).

The role of the student consists of a limited set of tasks to perform, while the teacher can perform more complex ones and the administrator can execute all possible tasks, including those of teachers and students. It may seem reasonable to test directly the LMS with the administrator's role for everyone, as in [11], however this situation does not mimic the real use of Moodle in a learning context. The different roles are not a simple collection of tasks, rather they represent true differences in terms of experience with the LMS and the logical hierarchy of responsibilities within the management of a real Moodle content system.
A student (not necessarily visually impaired) should be able to perform his/her tasks without prior knowledge of how Moodle works, since the LMS is so user friendly to students that after a brief description of its structure they are able to fruitfully use it. On the contrary, a teacher is required to undergo a certain amount of training in order to perform his/her tasks, since he/she is supposed to be able to insert, modify and create a course that fits his/her personal way of teaching. Moreover, usually students refer to their teacher when they have technical problems with the LMS. Finally, in order to become a system administrator one has to be familiar also with the more complex and more general tasks involved in creating and managing various courses, and to reply to all the questions and solve all the problems of teachers and students.
Since different roles correspond to different degrees of knowledge and experience with Moodle, we decided to divide the tasks not only on the basis of the role, but also with several participants playing the same role. As already noticed, this is a major difference from [11], were the whole evaluation was conducted using the administrator role only. The evaluation was performed by four participants:

- Three of them (see Table 4) played the role of the students. None had prior knowledge of the existence of Moodle. They received only a very short explanation of what the LMS is and what it is commonly used for; secondly they tested the students' tasks listed in Table 1.
- One participant (see Table 4) played the role of the teacher. He did not have prior knowledge of the existence of Moodle. He received an explanation of the way Moodle works, had the possibility to read the instructions' manual and had time to familiarize with the LMS. After this initial training phase, he was questioned about the comprehension of the basic instructions and he provided a positive feedback. Then he tested the teacher's tasks listed in Table 2. After completing all the tasks, he acquired a significant amount of experience, and received also the role of administrator in order to test the specific tasks listed in Table 3. Notice that first he assumed the role of the teacher, and then the role of administrator.

All these precautions were taken in order to mimic the real situation of a Moodle user, and to reduce the possibility of problems with tasks due to the lack of experience rather that real accessibility problems.

2.4 Participants

The evaluation was carried out by four participants as represented in Table 4. Each one used different Assistive Technologies (ATs) and a different combination of OS and Web browser. Three participants were blind (B) and one low vision (LV). It is to be noticed also that, while participant A is blind from birth, participants B

Table 1: Tasks of the student profile

Category	Task
General	Login user
General	Logout user
General	Find 'help' manual
General	Edit user profile
Course	Find a lecture
Course	Navigate inside a lecture
Course	Read the calendar
Course	Read the news
Course	Read the name of the participants of a course
Course	Read the profile of a course participant
Teacher	Open a forum
Teacher	Add a new topic in a forum
Teacher	Delete a topic in a forum
Teacher	Reply to a topic in a forum
Teacher	Open a chat
Teacher	Participate to a chat
Teacher	Send a private message to a teacher
Assignment	Open a link
Assignment	Open a file
Assignment	Read an assignment with plain text
Assignment	Read an assignment with mathematical content
Assignment	Upload a file
Assignment	Open a quiz with plain text
Assignment	Complete a quiz with plain text
Assignment	Read the evaluation of a quiz
Assignment	Open a quiz with mathematical content
Assignment	Complete a quiz with mathematical content

Table 2: Tasks of the teacher profile

Category	Task
General	Login user
General	Logout user
General	Find 'help' manual
General	Edit user profile
General	Activate the teacher profile
General	Switch to student profile
General	Create a folder
General	Upload a file
General	Download a file from a folder
Course	Edit the name of a lecture
Course	Edit the content of a lecture
Course	Move the content of a lecture
Course	Navigate inside a lecture
Course	Read the calendar
Course	Set a new event on a calendar
Course	Read the name of the participants of a course
Course	Read the profile of a course participant
Course	Read live log from the past hour
Course	Read activity report
Course	Read participation report
Course	Filter logs
Student	Create a forum
Student	Add a new topic in a forum
Student	Delete a topic in a forum
Student	Reply to a topic in a forum
Student	Create a chat
Student	Participate to a chat
Student	Send a private message to a student
Student	Create a poll
Student	Read the answers to a poll
Student	Read the logs of a poll
Assignment	Create a new assignment
Assignment	Edit the options of an assignment
Assignment	Upload a file of an assignment
Assignment	Create a quiz
Assignment	Create a new question with plain text
Assignment	Create a new question with mathematical content
Assignment	Export a question
Assignment	Import a question
Assignment	Read the overview report of a quiz
Assignment	Read the grader report of a quiz
Assignment	Read a student's report of a quiz

and C became blind later during their life. Participant A has a high school degree (EQF 4), participants B and D are attending university for a bachelor degree (EQF 5) while participant C is attending university for a master degree (EQF 6). Participants B, C and D are all in their twenties, while participant A is in his forties. One used Windows 7, one Windows 8 and two Mac OS X. Two used a refreshable braille display (BD), and two did not. Two used Voice Over (VO) as screen reader (SR), one used NVDA 2015.2 (currently one of the most commonly used screen reader available), and one did not use a screen reader, but the magnifying software Magic. Two used as web browser Safari 8, one Mozilla Firefox 41 and one Internet Explorer 11. None of them had previous knowledge of Moodle, and each received a different introduction to the LMS, as described in Section 2.3.

It is important to notice that we let all the participants use the combination of OS/WB and AT they were most familiar with and that they use in everyday life. This choice was made to reduce all the possible problems which can arise from lack of experience with the Assistive Technology or with the software, rather then with Moodle itself.

Finally, we point out that participant A was chosen to represent a teacher and an administrator because he is an IT expert with very high skills in managing Voice Over. However, we feel that all the accessibility problems he was able to overcome in order to perform his tasks because of his deep experience with IT, are also manageable by users with less experience, though with more time to experiment.

3 Outcomes of the evaluation

In this section we describe the results of the evaluation.

Table 3: Tasks of the administrator profile

Category	Task
General	Login user
General	Logout user
General	Find 'help' manual
General	Edit user profile
General	Activate the administrator profile
General	Switch to teacher/student profile
General	Create a folder
General	Upload a file
General	Download a file from a folder
Manager	Create a new course
Manager	Edit a course name
Manager	Add a new user
Manager	Edit a student/teacher profile
Manager	Remove a user
Manager	Define users' roles
Manager	Create the backup of a course
Manager	Restore a course from a backup
Manager	Add a new plugin to a course
Manager	Remove a plugin from a course

Table 4: Participants to the evaluation

Subject	Disability	Role	SR	BD	OS	WB
A	B	T/A	VO	Yes	Mac X	Safari 8
B	B	S	NVDA	Yes	Win 8	Mozilla 41
C	B	S	VO	No	Mac X	Safari 8
D	LV	S	No	No	Win 7	IE 11

Table 5: Errors of the tasks of the student profile

Task	Errors
Login user	**No**
Logout user	**No**
Find 'help' manual	**E1**
Edit user profile	**E1**
Find a lecture	**No**
Navigate inside a lecture	**No**
Read the calendar	**E1**, **E5**, **E6**, **E10**
Read the news	**E1**
Read the name of the participants of a course	**E1**, **E10**
Read the profile of a course participant	**E10**
Open a forum	**No**
Add a new topic in a forum	**No**
Delete a topic in a forum	**No**
Reply to a topic in a forum	**E13**
Open a chat	**No**
Participate to a chat	**E11**
Send a private message to a teacher	**E11**
Open a link	**E12**
Open a file	**E12**
Read an assignment with plain text	**No**
Read an assignment with mathematical content	**E4**, **E7**
Upload a file	**E2**, **E9**
Open a quiz with plain text	**No**
Complete a quiz with plain text	**No**
Read the evaluation of a quiz	**E1**
Open a quiz with mathematical content	**No**
Complete a quiz with mathematical content	**E4**, **E7**

3.1 Error types

User evaluation was conducted as discussed in the previous sections. While conducting our evaluation we limited ourselves to listing all the accessibility problems that came out during the completion of the various tasks. These diverse problems users faced while interacting with Moodle have been grouped and labeled as follows, according to the ideas in [11]:

- **E1**: Headings are not tagged correctly. In this case, the contents of the page can not be browsed with the specific commands of the screen reader;
- **E2**: A pop-up window opens without warning the user;
- **E3**: The control is unlabeled. In this case, the screen reader recognizes the control, but it can not be searched within the page by the specific commands of the screen reader. Moreover, when the screen reader encounter it, no description of the control is provided by the screen reader;
- **E4**: The mathematical content is not read correctly by a screen reader; Specifically, the screen reader reads an alphanumeric sequence that does not provide any information about the meaning of the mathematical content; Notice that all the mathematical content is generated only through the Moodle math editor. A detailed description of the mathematical content used in the test can be found in Section 3.3.
- **E5**: Plain-text content is not read correctly by a screen reader;
- **E6**: Refreshable braille display does not display correctly plain text content;
- **E7**: Refreshable braille display does not display correctly mathematical content;
- **E8**: The control is not recognized by the screen reader. In this case, the user is not able to use the control;
- **E9**: User is not advised that the task is finished. For instance, the screen reader can not be able to warn the user when the upload or download of a file is accomplished;
- **E10**: The table is so big the user cannot understand its overall structure;
- **E11**: The controls in the page structure are in the wrong order, making the completion of the task difficult;
- **E12**: Page refreshes without warning the user;
- **E13**: The controls present a tree-like structure which is difficult to understand.

3.2 Results

As an overall result, all participants were able to complete, with different degrees of difficulty, all the tasks of Table 1, Table 2 and Table 3. Therefore, we can conclude that Moodle is accessible to visually impaired people. However, as the present section demonstrates, different accessibility barriers were encountered in Moodle by the evaluation participants. Although these barriers were not severe enough to prevent each participant to fully perform a given task, users experienced important accessibility difficulties that made the use of Moodle more problematic.

Comparing the evaluation results obtained by users with different OS and different WB we did not find important differences in the accessibility of Moodle. A major exception to this rule concerns mathematical content, as detailed in Section 3.3. Also the problems encountered by participant B of Table 4, who used a refreshable braille display, and participant C, who did not, were not significantly different, except for some problems directly connected with the BD (errors **E6** and **E7** of Section 3.1).

A comprehensive list of the outcomes of the evaluation, divided by roles, is displayed in the following Tables 5, 6 and 7. If the participants were able to complete the task without accessibility barriers, we wrote '**No**' in the errors column.

We can see that the most frequent errors are **E1**, **E2** and **E9**, which deal directly with the use of the screen reader. It is important to notice here that certain errors, such as **E3**, although rare, carry important consequences in the accessibility of the LMS, making the completion of a task very difficult.

Figure 1 and Figure 2 show the number of errors for each of the six categories of Section 2.3, grouped together and divided by profile, respectively, while Figure 3 shows the number of errors divided by profile and task. We can see that the majority of errors appears in the categories 'Course' and 'Assignment', and this can be explained by the fact that these categories include tasks which require a higher degree of interaction with Moodle. Thus, an incorrect tag of the headings (error **E1**) or an unlabeled control (error **E3**) have more consequences in the completion of the task rather than in situations where the user is simple a passive reader of the content of the LMS.

As a final remark, we point out that the evaluation of tasks related to mathematical content only concerns what can be done by using the standard tools of Moodle, namely multiple choice questions, filling in the blanks and open questions where the student has to insert a number or a short sentence. More complex tasks, such as solving a mathematical problem, require the use of other software interacting with Moodle (e.g. MAPLE), and the accessibility problems related are beyond the scope of this assessment.

Table 6: Errors of the tasks of the teacher profile

Task	Errors
Login user	**No**
Logout user	**No**
Find 'help' manual	**E1**
Edit user profile	**E1**
Activate the teacher profile	**No**
Switch to student profile	**E1**
Create a folder	**E2**
Upload a file	**E2**, **E9**
Download a file from a folder	**E2**, **E9**
Edit the name of a lecture	**No**
Edit the content of a lecture	**No**
Move the content of a lecture	**E11**, **E9**
Navigate inside a lecture	**E1**
Read the calendar	**E1**, **E5**, **E6**, **E10**
Set a new event on a calendar	**E1**, **E5**, **E6**, **E10**
Read the name of the participants of a course	**E1**, **E10**
Read the profile of a course participant	**E10**
Read live log from the past hour	**E10**
Read activity report	**E10**
Read participation report	**E10**
Filter logs	**No**
Create a forum	**E2**
Add a new topic in a forum	**No**
Delete a topic in a forum	**No**
Reply to a topic in a forum	**E13**
Create a chat	**E2**
Participate to a chat	**E11**
Send a private message to a student	**E11**
Create a poll	**E2**
Read the answers to a poll	**No**
Read the logs of a poll	**E10**
Create a new assignment	**E2**
Edit the options of an assignment	**No**
Upload a file of an assignment	**E2**, **E9**
Create a quiz	**E2**
Create a new question with plain text	**E2**
Create a new question with mathematical content	**E2**, **E4**, **E7**
Export a question	**E1**, **E13**
Import a question	**E1**, **E13**
Read the overview report of a quiz	**E1**
Read the grader report of a quiz	**E1**
Read a student's report of a quiz	**E1**

3.3 Mathematical content

The Moodle text editor provides the possibility of writing mathematical expressions. A formula can be written by knowing the LaTeX language or by using the editor provided by default by Moodle. In the first case, it is sufficient to write the suitable LaTeX commands between \(and \). In the second case, it is necessary to click the button 'Equation Editor'. In this way a

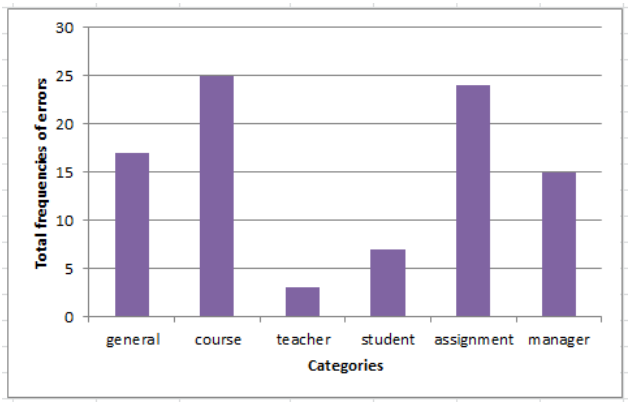


Fig. 1. Errors of each category.

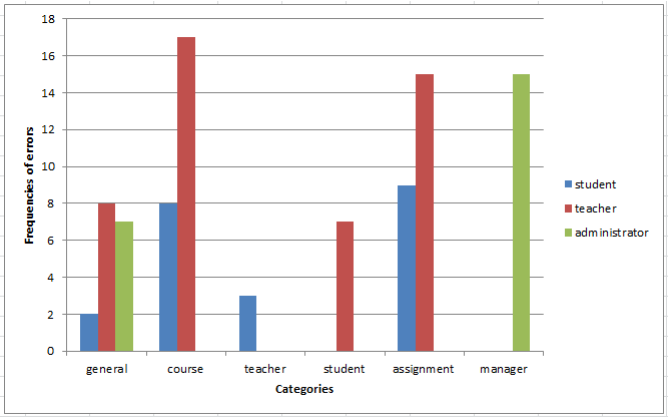
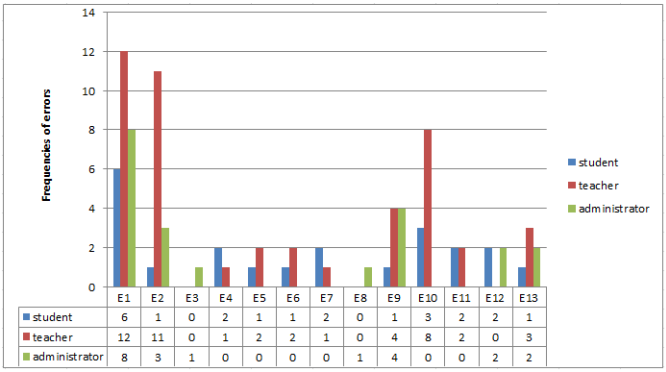


Fig. 2. Errors divided by profile.



	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13
student	6	1	0	2	1	1	2	0	1	3	2	2	1
teacher	12	11	0	1	2	2	1	0	4	8	2	0	3
administrator	8	3	1	0	0	0	0	1	4	0	0	2	2

Fig. 3. Errors divided by profile and task.

new window, where there are some buttons that simplify the input of formulae (also without knowing LaTeX language), is enabled. This mathematical editor is fully accessible since every button is tagged. However, screen reader users need the knowledge of LaTeX language also for using such an editor. Indeed, the labels of the buttons are named with the corresponding LaTeX commands. For further information on LaTeX we refer to [19].

Table 7: Errors of the tasks of the administrator profile

Task	Errors
Login user	**No**
Logout user	**No**
Find 'help' manual	**E1**
Edit user profile	**E1**
Activate the administrator profile	**No**
Switch to teacher/student profile	**No**
Create a folder	**E2**
Upload a file	**E2**, **E9**
Download a file from a folder	**E2**, **E9**
Create a new course	**E13**
Edit a course name	**No**
Add a new user	**E1**
Edit a student/teacher profile	**E1**
Remove a user	**E1**, **E3**, **E8**
Define users' roles	**E1**
Create the backup of a course	**E1**, **E13**
Restore a course from a backup	**E1**, **E13**
Add a new plugin to a course	**E9**, **E12**
Remove a plugin from a course	**E9**, **E12**

The issues above described have to do with the writing of mathematical content and they represent a specific feature of the Moodle text editor. On the other hand, the matter of reading mathematical content in Moodle is not different, in terms of the accessibility of formulae, from the general situation on the web.

Our purpose was to examine also this aspect of the study and the test participants gave us the following results. Formulae are rendered by default as annotated images (by means of the 'alt' attribute), where the alternate text corresponds to the LaTeX commands. Since assistive technologies can access the alternate text of an image, a visually impaired user can access these mathematical contents only knowing the LaTeX language. Alternatively, if 'Notation TeX' is disabled in the section 'Filters', formulae are rendered by MathJax. MathJax is a javascript widely used for the visualization of formulae on the web. Using MathJax a formula is not an image but a web object. In this case, the accessibility of a formula is affected by performances of screen readers, WB and OS. Specifically, these formulae are accessible on Windows with the screen reader Jaws 16 (or later versions) and the Internet Explorer browser. Furthermore, formulae rendered by MathJax can be switched to pure MathML formulae. This is possible, and the participants tested it by using the 'object navigation' option in the screen reader, by right clicking the formula and selecting the menus 'Math Settings', 'Math Render', 'MathML'. In this way formulae are accessible on Apple Mac with the screen reader VoiceOver and Safari. Moreover they are accessible on Windows with the screen reader NVDA 2015.1 (and later versions) and the Mozilla Firefox browser thanks to the free software

MathPlayer 4 (see [6], [20]). This solution allows to enable on braille displays the braille mathematical symbols with the possibility of choosing among Marburg Braille, Nemeth Braille, UKMaths Braille, and Woluve Braille.
In our test the teacher was able to create three different kinds of items containing mathematical content: two multiple choice questions and a short answer question. The first multiple choice question, depicted in Figure 4, is a simple mathematical question without the use of LaTeX. The second multiple choice question, depicted in Figure 5, required the use of LaTeX for the formulae. The short answer question, displayed in Figure 6, was created to test the accessibility of the box used to insert the answer. All three questions were assigned to all the students.

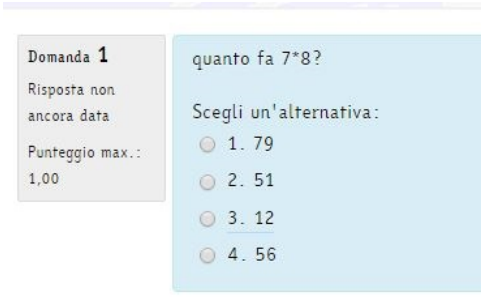


Fig. 4. The text says "How much is $7 \cdot 8$? Pick an alternative".

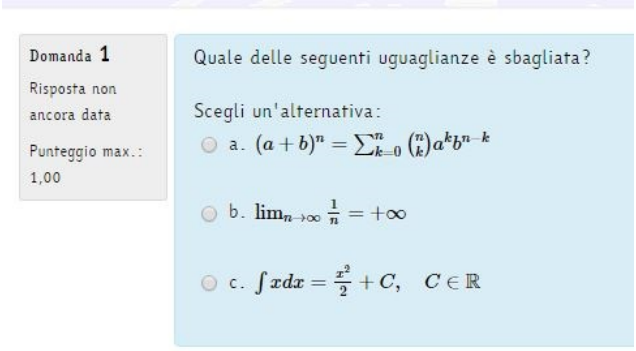


Fig. 5. The text says "Which of the following equalities is wrong? Pick an alternative".

4 Recommendations

Based on the results of the evaluation described in the present paper, we elaborated a set of recommendations

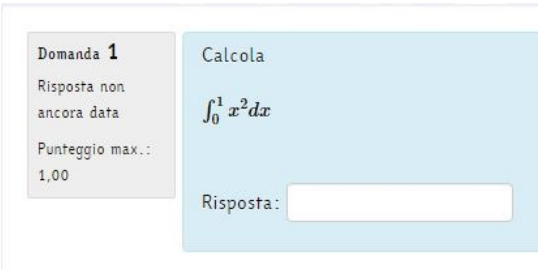


Fig. 6. The text says "Compute".

in order to improve the accessibility of Moodle and reduce the possible problems of a visually impaired user:

- To overcome errors **E1**, **E3** and **E8**, one should carefully check all the headings and controls of Moodle and ensure they are all tagged and labeled correctly. Since screen readers use headings and tags to make visually impaired users understand the structure of a page, solving these problems appears a major step towards the full accessibility of Moodle;
- To overcome errors **E2**, **E9** and **E12**, Moodle should tell the users via a voice command that a pop-up window just opened, that a given task (such as uploading a document) is finished, or that the page has just refreshed;
- Errors **E5** and **E6** are connected, since the braille display is developed in connection with the screen reader. Although rare (they only occurred in two tasks, see Table 5 and Table 6), these problems can be very difficult for a visually impaired user to overcome. To solve them, one should carefully check the text of the tag of the items involved in the task;
- As in the previous observation, errors **E4** and **E7** are connected, and they come from the problems with the Moodle text editor with mathematical content addressed in Section 3.3. A possible solution to these problems, as far as we know, appears to spread the use of the LaTeX language to the visually impaired users dealing with mathematical content. The learning of LaTeX for visually impaired users (including blind users), has proved to be reasonably achievable and suggested by various studies, such as [18], [17], where a blind student explains how she got her master degree in mathematics with the substantial aid of LaTeX, and [8]. We are well aware of the existence of various LaTeX or MathML to Nemeth converters, however there is not a single standard Braille for mathematics, for instance Nemeth is used mostly in English native-speaking countries. Moreover, it appears more natural to find a solution involving the LaTeX language in this specific context, since Moodle's formulae editor is LaTeX based;

- Error **E10** is a common error that can be encountered while dealing with tables. There is extensive literature addressing the accessibility of tables, see, e.g., [21];
- To solve **E11**, the controls should be placed, in all the tasks involved with the error, in a different order. A clear example is the position of the button used to open the accessible version of the chat ('Versione accessibile') that should be placed before the button of the simple and not accessible chat ('Entra nella chat'), in order to be read immediately by the screen reader;
- To solve error **E13** Moodle should simply avoid tree-like structures in all the controls. For instance, this error occurred when trying to navigate the "Report" menu in the "Administration" section.

As a final remark, we would like to point out that the solutions for most of the problems we encountered require only small modifications on the layout of Moodle and, therefore, appear to be solvable with a relatively small effort. The Moodle team will be informed of our suggestions after the publication of this paper.

5 Conclusions

We have performed a targeted evaluation of the accessibility of the Moodle 2.7 platform. The evaluation has been conducted with the aid of four visually impaired test participants by using different assistive technologies (screen readers NVDA and VoiceOver, braille displays and magnifiers), operating systems (Windows 7, Windows 8, Mac OS X) and browsers (Internet Explorer 11, Mozilla Firefox 41, Safari 8).
During the tests all participants were generally able to complete all the required tasks. For this reason, we can state that Moodle can be considered accessible to visually impaired people. The relatively small number of participants does not affect this conclusion, since if a task is accessible for a single user then the definition of accessibility is reached. Notice that, while accessibility is a matter of the task itself, the concrete possibility for users to complete it is connected to various issues including the skills of the users, the acquaintance with the LMS and the combination of tools that are used. However, these factors are not analyzed in the present work. Some levels of criticality regarding Moodle's accessibility have been observed, even if they did not prevent each participant to fully perform a given task.
As further development of the present work, we would like to extend our study to Windows 10. Some preliminary tests have already been conducted showing that the overall performance of the assistive technologies is unaltered. Moreover, it would be interesting to carry out an evaluation taking into account which assistive technologies are more suitable to work with Moodle, and with the aid of more participants for the roles of Teacher and Administrator.

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