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MOOCs for all: Evaluating the accessibility of top MOOC platforms*

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Nowadays, experiences with massive open online courses (MOOCs) are being part of modern engineering degrees, thus providing practical interactive activities to improve teaching-learning strategies with online courses and social community learning with peers from different countries. Additionally, this MOOC movement is being identified as a valuable tool to provide engineering education to all students, including students with disabilities that for different reasons cannot be part of a face-to-face session and, naturally, have the rights to make use of this myriad of teaching-learning strategies. In this sense, if a teacher wants to develop a MOOC course or to recommend a course to his students, it is imperative to identify the best accessible platforms in order to provide inclusive learning strategies. The aim of this study is to analyze the accessibility of a selection of eight popular MOOC platforms: Coursera, edX, Udacity, MiriadaX, UNED COMA, Udemy, Futurelearn and NovoEd. To this end, three automatic accessibility evaluation tools have been used: eXaminator, FAE and Tingtun. Hence, it has been checked the degree of conformance of these platforms with the Web Content Accessibility Guidelines (WCAG) created by the World Wide Consortium and adopted by ISO as an international standard. The study has been complemented with a heuristic evaluation by experts in order to have a holistic perspective of MOOC accessibility. The idea behind this study is that the stakeholders in the teaching-learning process will be able to identify and select the most inclusive platform based on the international standards. Moreover, the technical staff in educational institutions will be provided with a procedure to identify accessibility issues in other platforms and engineering teachers will be aware of the potential obstacles that students with disabilities may experience. The results of this study identify edX and Futurelearn as the best MOOC platforms. Finally, conclusions and future work ideas are presented.

Keywords: web content accessibility; usability; disability; WCAG 2.0; MOOC

1. Introduction

Since their inception, MOOCs (Massive Open Online Courses) have grown exponentially, with a higher increase even than social networks [1]. In a very short time, initiatives such as Khan Academy [2] have reached vertiginous data. This movement is considered by some authors as the most important technological innovation in the last 200 years [3]. Nevertheless, they are subject of study due to the lack of a defined model [4]. Recent studies question the quality of MOOCs [5] and evaluate them. Results show high scores in organization and presentation of course materials, but the quality of the instructional design is low [6]. The Quality Assurance Agency for Higher Education (QAA) has presented a collection of the more relevant trends [7], and it shows that it is necessary future investments in the pedagogical principles of the MOOC model. Among them, personalization of the learning experience for learners with differing needs appears as one of the seven keys for a quality assurance [8].

MOOCs, together with OCW (OpenCourseWare) and other Open Education initiatives offer the possibility to expand access to knowledge worldwide, helping to eliminate geographical and financial barriers between students, teachers and self-learners [9]. On the other hand, there are some obstacles to achieve this target: some legal, technical, financial and social aspects must be addressed [10]. Among them outstands the need to significantly improve the discovery, accessibility and visibility of open educational content [11].

In the context of higher education, MOOCs fit the profile of the student because the topics are integrated with higher education programs [5]. Even more in engineer education, not only because of their ability to accept technology as shown by some studies [12], but because they have experience handling OER as having used OSS (Open Source Software) [13] and they need to be constantly updated, expanding knowledge and developing new skills for the development of their profession [14]. Therefore, MOOCs are considered as a possible solution for continuous training [15].

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The UNESCO "Education for all" Movement, in particularly in their two first goals, says that a quality education must be offered, and it is necessary to favor the most vulnerable and disadvantaged, especially those in difficult circumstances. People with disabilities make up ten per cent of the world's population and UN alerts that currently there are no references to people with disabilities in the Millennium Development Goals (MDG). Therefore, UN suggests the creation of tools and guidelines that would be effective entry points to mainstream disability in monitoring of MDG policies, processes and mechanisms [16].

In a broad sense, accessibility can be defined as the condition that must meet environments, products and services to be understandable, usable and practicable for everybody, including people with disabilities. Accessibility is largely related to quality. In fact, most quality models consider accessibility as part of the study. MOOCs are an opportunity to offer high quality engineer education to all motivated and talented students regardless of their background, whether they belong to vulnerable and disadvantaged groups or have difficult circumstances. Nevertheless, not in all cases are these courses and platforms ensuring the guidelines established for a proper accessibility. It is very important to guarantee the correct access to this kind of courses for everybody, moreover people with personal disabilities or disadvantaged environments.

This paper is organized as follows: First, a state of the art is presented with the main accessibility requirements and guidelines that a web-based platform should follow. This section is complemented with a literature review of related works on recent studies about MOOC accessibility. Then, in section 3, the purpose of the study and objectives are presented. An analysis of the accessibility of a selection of eight popular MOOC platforms is performed based on the Website Accessibility Conformance Evaluation Methodology, which includes techniques using automatic tools, disability simulation tools, testing tools and personal analysis of the educational contents and the pedagogical aspects. Section 4 presents the results of the study where the edX and Futurelearn MOOC platforms are the best rated ones. Finally, a discussion and conclusions are presented.

2. Literature review

2.1 Accessibility requirements and guidelines

There is a large number of norms and standards that indicate how to obtain a correct web design with an appropriate accessibility level [17]. To guarantee web accessibility we must consider the Web Content Accessibility Guidelines 2.0 (WCAG 2.0) published by the Web Accessibility Initiative (WAI) of the World Wide Web Consortium (W3C) in 2008 [18], and adopted as ISO standard in 2012 [19]. WCAG 2.0 is important, not only for having become standard ISO, but also because many countries have created laws based on this standard. For instance, Spain created a law that forces publicly funded websites and websites of relevance to citizens, such as universities or schools, to meet the standard in 2007. At present, the European Union is debating a new law similar to the Spanish one, which will be applied in the future to all websites in the member countries [20].

WCAG 2.0 components are principles, guidelines and success criteria. Based on the four principles of web accessibility (perceivable, operable, understandable, and robust), there are twelve guidelines that provide basic goals in form of a total amount of 61 success criteria (Table 1). In addition, three levels of conformance are established (A, AA and AAA) for websites, depending on the success criteria met. To get level A, 25 criteria have to be met. To get level AA, besides the aforementioned, 13 more criteria have to be met. Level AAA is obtained when all 61

Table 1. Accessibility principles, guidelines and success criteria established in WCAG 2.0

Principles (4)	Guidelines (12)	Success Criteria (61)
1. Perceivable	1.1 Provide text alternatives	1
	1.2 Provide alternatives for time-based media	9
	1.3 Create adaptable content	3
	1.4 Make content distinguishable	9
2. Operable	2.1 Make all functionality available from a keyboard	3
	2.2 Provide users enough time to read and use content	5
	2.3 Do not design content in a way that cause seizures	2
	2.4 Provide ways to help users navigate	10
3. Understandable	3.1 Make text content readable and understandable	6
	3.2 Make Web pages appear and operate in predictable ways	5
	3.3 Help users avoid and correct mistakes (input Assistance)	6
4. Robust	4.1 Maximize compatibility with user agents	2

Table 2. Some relevant WCAG 2.0 success criteria of level A and AA

Success Criteria
1.1.1 Non-text Content: All non-text content that is presented to the user has a text alternative that serves the equivalent purpose.
1.2.1 Audio-only and Video-only (Prerecorded): For prerecorded audio-only and prerecorded video-only media, an alternative is provided.
1.2.5 Audio Description (Prerecorded): Audio description is provided for all prerecorded video content in synchronized media.
1.3.1 Info and Relationships: Information, structure, and relationships conveyed through presentation can be programmatically determined or are available in text.
1.4.3 Contrast (Minimum): The visual presentation of text and images of text has a contrast ratio of at least 4.5:1.
2.1.1 Keyboard: All functionality of the content is operable through a keyboard interface without requiring specific timings for individual keystrokes.
2.4.1 Bypass Blocks: A mechanism is available to bypass blocks of content that are repeated on multiple Web pages.
2.4.4 Link Purpose (In Context): The purpose of each link can be determined from the link text alone or from the link text together with its programmatically determined link context.
2.4.6 Headings and Labels: Headings and labels describe topic or purpose.
3.3.2 Labels or Instructions: Labels or instructions are provided when content requires user input.
4.1.1 Parsing: In content implemented using markup languages, elements have complete start and end tags, elements are nested according to their specifications, elements do not contain duplicate attributes, and any IDs are unique.
4.1.2 Name, Role, and Value: For all user interface, the name and role can be programmatically determined; states, properties; and notification of changes to these items is available to user agents, including assistive technologies.

criteria are met. As an example, Table 2 shows some success criteria to reach level A and AA. These criteria have been highlighted from the rest of criteria because, as it will be shown in the next sections, they are not accomplished by the MOOC platforms analyzed.

2.2 Related works

Concern for the analysis of the accessibility in the education context is object of continuous study. Some researches analyze the accessibility with a global perspective, and their findings show differences in the accessibility of the universities web pages [21]. Traditionally, studies have focused in the accessibility of the learning management systems; however, the new trends (with the open and massive environment) promote the debate on the accessibility of the MOOCs and platforms. Some studies analyze the accessibility of MOOCs and, after identifying the major problems, authors offer recommendations to avoid them [22, 23]. On the other hand, developers of MOOC platforms have published guidelines and recommendations to facilitate the accessibility enforcement to MOOC authors in their platforms. In that regard, it is important to note the accessibility best practices published in edX [24], and grouped by the twelve guidelines shown in Table 3.

Recent studies were also published about accessibility courses, showing the analysis of a specific knowledge and focused on a kind of student limitation. Sanchez-Gordon and Luján-Mora [25] showed a specific study about engineering in MOOC, and presented the base for establishing criteria for a preliminary selection of MOOCs as creditable courses in engineering programs at a Polytechnic School for non-native speakers. They identified 17 relevant WCAG 2.0 criteria for improving the accessibility of MOOCs: 6 correspond to level A, 4 to level AA, and 7 to level AAA. Same authors in other study [26], analyzed accessibility problems and possible solutions in MOOCs intended to elderly students. These studies are referred to the accessibility of the MOOC contents, while related works to the study here presented are focused in the analysis of the accessibility platform. If a MOOC platform has accessibility conflicts, it becomes a barrier for disabled students when they try to take any course: common tasks as login, search, forums, content navigation, etc. can be complex and even impossible for these students.

Table 4 shows a compilation of the most recent studies. First column indicates the study reference,

Table 3. Accessibility Guidelines for MOOC developers recommended by edX

General Guidelines
Use semantic markup.
Make images accessible.
Avoid using CSS to add content.
Include a descriptive title attribute for all <iframe> elements.
Make sure form elements have labels.
Include link and control labels that make sense out of context.
Use WAI-ARIA to create accessible widgets or enhance native elements.
Manage the focus for pop-ups.
Inform users when content changes dynamically.
Hide or expose content to targeted audiences.
Choose colors that meet WCAG 2.0's minimum contrast ratios.
Test your code for accessibility.

Table 4. Recent studies about MOOC accessibility

Reference	MOOC Platform evaluated	Automatic tools used	Sections	Evaluation
(Sanchez-Gordon and Luján-Mora, 2013) [26]	Coursera	-	4	Heuristic evaluation by experts.
(Iniesto and Rodrigo, 2014) [27]	UNED COMA COLMENIA MiriadaX	eXaminator aDesigner SortSite	6	Heuristic evaluation by experts.
(Iniesto, Rodrigo and Moreira, 2014) [28]	UNED COMA UAb iMOOC	eXaminator aDesigner	6–9	Heuristic evaluation by experts.
(Al-Mouh, Al-Khalifa and Al-Khalifa, 2014) [29]	Coursera	NVDA VoiceOver WAVE Toolbar WCAG Contrast checker Accessibility Evaluator Toolbar	10	Heuristic evaluation by experts, and User evaluation (2 blind persons and 1 blindfolded sighted person).
(Bohnsack and Puhl, 2014) [30]	edX Coursera Iversity OpenCourseWorld Udacity	JAWS	–	User evaluation by a blind person. The experiment stops when a blind person finds a barrier. Only edX has no barriers.
(Flórez, Ruiz, Castaño, Tabares and Duque, 2014) [31]	Coursera Canvas CodeAcademy	TAW	1	Heuristic evaluation by experts.
(Pascual, Castillo, Garcia-Diaz and González, 2014) [32]	Coursera edX Udacity Udemy MiriadaX MIT	SortSite AChecker Pigdom	–	Heuristic evaluation by experts.

second column shows the MOOC platforms evaluated and ordered according to their accessibility accomplishment (First platform on the top of each list is the most accessible in the study, and the last platform at the end of the list is the lowest accessible in the study). Third column shows the tool used in the evaluation, forth column shows the number of sections evaluated and the last column shows the method of evaluation. All studies used WCAG 2.0 guidelines for their measurements and an expert performed the evaluation, except in the case of Bohnsack and Puhl evaluation [30], in which a blind person performed the evaluation and no guidelines were followed.

3. Method

3.1 Purpose of the study and objectives

It is important to mention that the MOOC movement started with technological courses, especially with subjects related to Computer Sciences based on courses from Systems and Electronic Engineering. This important fact is presented in Table 5, which shows a selection of eight popular MOOC platforms, highlighting the high percentage of courses with subjects related to engineering degrees.

The aim of this study is to analyze the accessibility of eight different MOOC platforms: Coursera, edX, Udacity, MiriadaX, UNED COMA, Udemy, Futurelearn and NovoEd. In this sense, if a teacher wants to develop a MOOC course or wants to recommend a course to his students, it is imperative to identify the best accessible platforms in order to provide inclusive learning strategies. The idea behind this study is that the stakeholders in the teaching-learning process will be able to identify and select the most inclusive platforms based on the international standards presented in section 2.1. Moreover, the technical staff in educational institutions will have a procedure to identify accessibility issues in other platforms and engineering teachers will be aware of the potential obstacles that students with disabilities may experience.

3.2 Procedure

Website Accessibility Conformance Evaluation Methodology (WCAG-EM) [33] has been used to analyze the different MOOC platforms. This methodology is independent of tools, browsers and technologies. It can be applied to all website including web apps and mobile webs. It is based on the measurement of the WCAG 2.0 guidelines. WCAG-EM can be used to analyze complete websites, distinguishing open access web from login required-access. The initial step is the selection of the kind of pages to be analyzed. It is important to

Table 5. List of selected MOOC platforms highlighting the percentage of engineering related courses

Id	Platform	No. active courses	No. engineering related courses	No. users	URL
1	Coursera	1195	665 (56%)	11,800,000	www.coursera.org
2	Udemy	32,000	6,658 (20%)	8,000,000	www.udemy.com
3	edX	674	560 (80%)	4,000,000	www.edx.org
4	Futurelearn	267	61 (23%)	2,280,000	www.futurelearn.com
5	Udacity	99	96 (95%)	1,600,000	www.udacity.com
6	MiriadaX	84	37 (44%)	1,509,000	www.miriadax.net
7	NovoEd	84	17 (20%)	not available	www.novoed.com
8	UNED COMA	3	1 (33%)	not available	coma.uned.es

select different pages that collect the representative functions of the student tasks, and are varied in technology, style or interaction. Table 6 shows the different sections selected in this study to be evaluated in all the MOOC platforms.

3.3 Tools

The seven studies presented in Table 4 used different tools to perform automatic evaluations to test accessibility. From them, more than 10 automatic accessibility evaluation tools were identified. Each of the tools was examined, finding that only the tool *eXaminator* [34] provided a score based on the accessibility of individual web pages. In order to increase the coverage of accessibility criteria and to provide balanced results, two additional tools that provide accessibility scores were selected, these tools being *FAE* [35] and *Tingtun* [36]. It is important to mention that none of the accessibility studies available in literature makes use of these powerful tools, hence, this study intends to provide a holistic accessibility evaluation to provide an alternative point of view related to accessibility in MOOC platforms.

The first tool used, *eXaminator*, is a free web service to check the accessibility of any web page provided by Carlos Benavídez [34]. *eXaminator* allows checking the correct application of the WCAG 2.0 guidelines on the HTML and CSS contents. It calculates the accessibility of the webpage in a fast review and shows the success criteria according to their priority in a final summary, with an overall score from 1 to 10. This tool is easy to use, but evaluation does not cover the complete success criteria in WCAG 2.0.

The second tool used is the *Functional Accessibility Evaluator* (*FAE),* developed in the University of Illinois [35]. This tool is based on a set of five principles: Navigation and Orientation, Text Equivalents, Scripting and Automation, Styling, and Standards Coding techniques. Unlike other tools, which search for specific tags and attributes, such as img tags with no alt attribute, the FAE tool bases the evaluation on the coding techniques recommended in the Best Practices, essentially applying the Best Practices coding examples as rules for the evaluator. FAE offers an overall accessibility score from 1 to 100. Fig. 1 shows an example of the application of the FAE-based tool in one of the evaluated platforms.

The third tool used is *Tingtun* [36]. It can be used with web and pdf documents. This Norwegian project was boosted when a Norwegian law on discrimination and accessibility came into force in July 2013, thus establishing that all Norwegian websites had to be universally designed to assure access for all. The tool presents a concise report; with results the webmasters understand so they can address the identified barriers. The report covers a high-level aggregation of results and observations, as well as hints for repairing with detailed raw data for technical staff. The project evolved to the EIII Checker, and it is actually developed by the European Internet Inclusion Initiative project, pre-

Table 6. Sections selected to analyze in MOOC platforms

Id	Page	Description	Location
1	Home	Main page of MOOC website platform	Public
2	Registration	Page to create a new user in the website	Public
3	Search	Page to search MOOC courses in the website	Public
4	Inscription	Page to enroll in one of the MOOC course offered in the website	Public
5	Help	Help or general information for the student	Public
6	Course	Main page or control panel inside a MOOC course	Private
7	Contents	Page with content index of the MOOC course	Private
8	Text	Page inside a MOOC course with text content	Private
9	Video	Page inside a MOOC course with audiovisual content	Private
10	Forum	Forum inside MOOC course with the possibility of edition	Private
11	Quiz	Page with self-assessment test	Private
12	Progress	Page with information about the student progress	Private

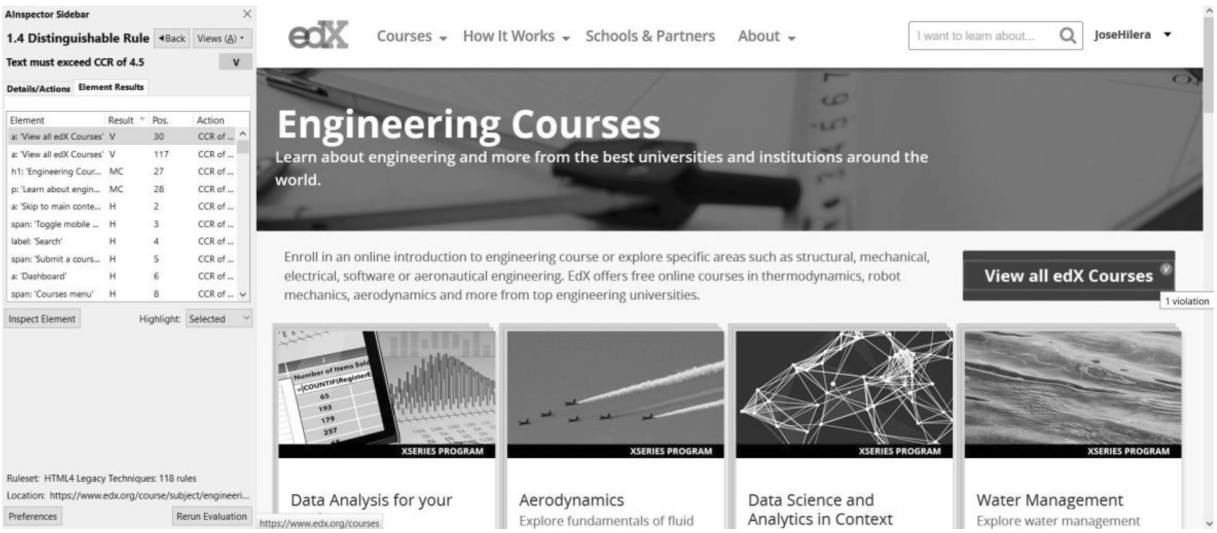

Fig. 1. Example of the application of a FAE-based tool highlighting the detected accessibility issues.

pared to provide services to web pages and PDF documents for accessibility. The page checker automatically detects barriers in Web documents (HTML and XHTML), according to WCAG2.0. *Tingtun* also offers an overall accessibility score from 1 to 100.

4. Results

In this study, each of the MOOC platforms were divided into two sections: the public site or external MOOC and the private site or internal MOOC. The external MOOC section is composed by all the pages that are available for every user. These pages are clearly identified in Table 6, including among them: the main page of the platform, the page to register as new user, the help pages and tutorials to use the educational platform and the search engine interface to explore the available courses. The internal MOOC is the section of all pages that only registered users are able to visit. These group of pages include the unique pages of a course where students interact daily with the learning contents, examples of these pages are: the home page of a course, the pages with learning content, the interface of time-based media including video and audio, the interface for the discussion forums and the interactive application for online tests for evaluation purposes.

It is important to mention that the internal or private site of a MOOC platform requires a login from registered students. In this sense, the open accessibility testing tools, which use the public URL of the page to be evaluated, are restricted to be used efficiently within the external MOOC section. Consequently, to solve this drawback, the private pages of each MOOC platform were carefully downloaded and replicated in a public test environment for an appropriate accessibility evaluation. Complementarily, in each of the identified private pages a complete heuristic evaluation was performed by a professional, with proved experience in accessibility, conformance criteria and the way in which students with different disabilities interact with web applications.

In this study, 36 automatic evaluation tests were run for the eight selected MOOC platforms in Table 5, thus giving a total of 288 accessibility tests using the three evaluation tools described in section 3.3. Each of the automatic evaluation tools provided a score according to their specific mathematical relationship based on the evaluation of more than a hundred accessibility success criterion rules. The scores obtained for each page were different depending on the evaluation tool. Based on this, the results average was calculated for each page and a final score was assigned for each platform as depicted in the column titled: ''overall automatic evaluation'' in Table 7.

With the purpose of identifying the accessibility differences between public and private pages in a MOOC, the final score for public and private pages is divided and presented in Table 7, showing a slight difference, as public pages report a better accessibility performance. It is important to raise awareness that students should have an improved accessibility experience in private pages, based on the fact that they spend most part of their time interacting with the learning content published in the internal MOOC section. Additionally, in this study a detailed heuristic evaluation was performed by two experts for each of the MOOC platforms, to identify the accessibility issues that the automatic evaluation tools are not able to identify. Table 8

Table 7. Results from accessibility evaluation of MOOC platforms

Order	Platform	Overall automatic evaluation	Public pages automatic evaluation	Private pages automatic evaluation	Expert evaluation Number of accessibility success criteria not met
1	edX	91.73	93.00	90.74	5
2	Futurelean	74.56	77.07	72.76	11
3	UNED COMA	78.25	83.53	74.48	15
4	NovoEd	72.91	73.00	71.64	16
5	Coursera	69.03	67.93	69.81	16
6	MiriadaX	63.33	64.53	62.48	18
7	Udemy	62.69	63.40	62.19	20
8	Udacity	58.94	58.00	59.72	22

presents a score based on the number of accessibility criteria failures in the column titled: "heuristic evaluation". In this case the platforms with the fewer errors are the most valued ones.

In Table 7, the eight MOOC platforms evaluated in this study are presented based on the identified level of accessibility in the following order, starting with the best evaluated MOOCs: edX, Futurelearn, UNED COMA, NovoEd, Coursera, MiriadaX, Udemy and Udacity.

Moreover, table 8 shows in detail the WCAG 2.0 accessibility Success Criteria (SC) of levels A and AA that were not fulfilled by the eight platforms (100%). In this table appears only the SC code, whose description can be found in Table 2. There are two success criteria that any of the MOOC platform satisfied: 1.3.1 and 4.1.2. The first is related to the logical structure of the page, and the main problems arise because in many cases HTML attributes are used to control the visual presentation of the pages instead of using CSS styles. In other cases, there are problems with page heading, some pages and tables headers are missing or are not correctly nested. On the other hand, the 4.1.2 SC problems detected are mainly because of links, form controls and frames with no name or a duplicated one.

There are four success criteria that seven platforms (87%) did not meet: 1.4.3, 2.4.1, 3.3.2 and 4.1.1. The first is based on the low contrast ratio of text in several pages. The SC 2.4.1 is not fulfilled because it is not possible to skip content blocks and because the first link of the pages does not go to the main content of the page. The problem with 3.3.2 is that in many cases there is no label in form controls that could clearly identify its purpose and the alternatively usable title is also missing. Many platforms did not meet also SC 4.1.1 because there are a lot of HTML elements with duplicated IDs.

Other four success criteria are not met by six platforms (75%). These are: 1.1.1, 1.2.5, 2.1.1 and 2.4.6. The first is because there are images without alternative text. The SC 1.2.5 is not fulfilled because there is video content with no audio-description, and the platforms do not offer a general mechanism to guarantee it in every course. The problem with 2.1.1 is that not all functionality is operable through a keyboard. And regarding 2.4.6, there are empty headings and lack of labels that describe the topic or purpose.

Finally, two more success criteria are not met by five of the MOOC platforms (62%): 1.2.1 and 2.4.4. The SC 1.2.1 is not fulfilled because no alternative is provided for pre-recorded video-only media, and the platforms do not offer a general mechanism for guarantee this in every course. The problem with SC 2.4.4 is that there are links whose purpose cannot be determined from the link text.

5. Discussion

Based on this experience, the two most valued platforms are firstly edX, and secondly Futurelearn.

Table 8. Success Criteria (SC) of levels A and AA not met by more than 50% of MOOC platforms

SC	edX	Future Learn	UNED COMA	NovoEd	Coursera	MiriadaX	Udemy	Udacity
1.3.1	x	x	x	x	x	x	x	x
4.1.2	x	x	x	x	x	x	x	x
1.4.3	x		x	x	x	x	x	x
2.4.1		x	x	x	x	x	x	x
3.3.2	x		x	x	x	x	x	x
4.1.1	x	x		x	x	x	x	x
1.1.1			x	x	x	x	x	x
1.2.5			x	x	x	x	x	x
2.1.1			x	x	x	x	x	x
2.4.6		x	x		x	x	x	x
1.2.1			x	x		x	x	x
2.4.4		x			x	x	x	x

Coincidentally, it is important to mention that both platforms, edX and Futurelearn are the only platforms that have a public accessibility statement published in their websites, stating their commitment to provide an accessible platform according to their national laws. In the first case, edX is a platform leaded by the Massachusetts Institute of Technology and Harvard University, institutions in the United States of America, thus following the accessibility law Section 508 of the Rehabilitation Act [37]. In the second case, Futurelearn is a platform leaded by The Open University, an institution with an important advocacy towards accessibility that follows the laws enforced in United Kingdom by the British Standard 8878 [38].

For the purpose of validating the results of this study, these findings were compared with the conclusions from the works presented in Table 4. As a starting point, the work presented in [27], presented the following order: UNED COMA, COLMENIA and MiriadaX. This order is in line with the results of this study coinciding with the first and third platforms. On the other hand, it is done the comparison with the work in [30] which is relevant because it was evaluated by a blind person, considered as a building block of the heuristic evaluation involving final users with disabilities. In this study the order was: edX, Coursera, Iversity, OpenCourseWorld and Udacity. For this second study, the results are in line with the findings in this research, where edX was best evaluated than Coursera and Udacity was in the last place.

Interestingly, the work in [32], is completely different from the study here presented. In this third work the order is as follows: Coursera, edX, Udacity, Udemy, MiriadaX and MIT, while the order in this study is: edX, Futurelearn, UNED COMA, NovoEd, Coursera, MiriadaX, Udemy and Udacity. Evidently, the results are mixed in different order. In this case it is important to mention that the study in [32] used only two accessibility evaluation tools: AChecker and SortSite. A third tool was identified as Pigdom but it does not provide a score based on accessibility. As a conclusion, regarding the procedure identified in the study in [32], it had a focus on the external MOOC as identified in section 4, and relied on a few automatic tools that in some cases may hinder a holistic evaluation. Despite these clear differences with the study in [32] the overall experience provided interesting findings and valuable tools to be used as a support for the technical staff in any educational institution.

Accessibility results have not showed relation with the popularity of the platform neither with their public or private nature. Coursera is the most popular platform with the highest number of users, followed by Udemy (Table 5). However, Table 7 illustrates that edX is the most accessible, while Coursera is in the fifth place and Udemy in the seventh.

Experiences with massive open online courses (MOOCs) are being part of modern engineering degrees, thus providing practical interactive activities to improve teaching-learning strategies with online courses and social community learning with peers from different countries. It is important to mention that the nature of the MOOC movement is clearly related to engineering and more than a fifty percent of the courses available in the different platforms are related to subjects involved in engineering degrees. Moreover, the MOOC movement is a valuable learning strategy to provide engineering education to all students in a worldwide community, but especially including students with disabilities that for different reasons can be part of a face-to-face session and naturally have the rights to make use of this myriad of teaching-learning innovative strategies.

In this study, accessibility of the eight most popular MOOC platforms was analyzed technically based on the fulfillment of the WCAG 2.0 guidelines. In future studies, not only technical aspects could be considered, but also it is important to analyze that the pedagogical concepts meet other specific guidelines about inclusive e-learning [39, 40]. Besides, a complementary study could focus on the accessibility analysis inside the MOOC courses. This will be a complex endeavor because the accessibility depends also on the authors work, and it depends on whether they took care about the accessibility guidelines when they developed the teaching materials (documents, presentations, videos, etc. [41]). However, if the platform is not accessible, the resources will not be used, and the first priority is to ensure the accessibility of the platforms as it was analyzed in this study. On the other hand, if the platform is accessible but the learning content is not accessible, the overall MOOC course will not be accessible at all. Bearing this in mind it is important to highlight that accessibility is a continuous task involving not only technology but also the stakeholders in the teaching-learning process.

6. Conclusion

The main result of this study identified the level of accessibility of MOOC platforms in the following order, starting with the best evaluated MOOCs: edX, Futurelearn, UNED COMA, NovoEd, Coursera, MiriadaX, Udemy and Udacity. With this in mind, if a teacher wants to develop a MOOC course or wants to recommend a course to his students, the

teacher should have as his first options edX and Futurelearn. Moreover, the technical staff in educational institutions should follow the Website Accessibility Conformance Evaluation Methodology (WCAG-EM) and they are encouraged to use as support to their own evaluations the powerful accessibility tools: eXaminator, FAE and Tingtun.

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