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LONG PAPER

Evaluation of authoring tools under ATAG and WCAG recommendations

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Abstract
Authoring tools are software programs that allow users to create learning content, lessons, and courses, usually to be used in virtual learning environments. These tools are a reasonable choice for novice users, as they use pre-programmed elements and do not require specific programming skills. However, they do not always meet accessibility guidelines, nor do they ensure that the educational content generated through them is accessible. This study first evaluates the accessibility of four popular free open-source authoring tools based on the ATAG recommendations. Then it evaluates the accessibility of the educational content generated through them based on the WCAG recommendations. These evaluations allow us to identify the level of accessibility of the authoring tools and their potential to help people with disabilities to become not only consumers but also producers of accessible educational content. We conclude that, while much work remains to be done to ensure accessibility, authoring tools are a potential key to effective social inclusion. Based on the findings of this study, we establish a set of recommendations for stakeholders to help close some gaps regarding accessibility.

Keywords Accessibility · Authoring tool · ATAG · Education · Disability · WCAG

1 Introduction

Information and communications technology (ICT) has emerged as a vital tool in supporting learning processes by providing multimedia educational content that enriches virtual learning environments (VLE) [1]. Some of this educational content is developed by experienced programmers who use specialised software; however, people without programming skills can also develop educational content by using authoring tools. An authoring tool is a software program that enables users to create learning content, lessons, and courses using pre-programmed elements. The use of authoring tools has increased recently, and, consequently, the amount of available educational content has also increased [2]. This increase may be because authoring tools eliminate the need for specific programming skills, enabling more users to produce multimedia educational content. Most authoring tools, however, have two inclusion issues. First, these tools present accessibility barriers that prevent people with disabilities from producing educational content. Second, the educational content created through most authoring tools does not meet accessibility guidelines, meaning people with disabilities may find it difficult to access such content [3].

The World Health Organization (WHO) defines disability as an umbrella term that covers impairments and activity limitations (motor, cognitive, visual, auditory, and others). The term 'impairments' refers to problems in body function and structure, while 'activity limitations' corresponds to difficulties that some people have with executing actions. According to the WHO, more than one billion people worldwide live with some form of disability, a figure expected to increase to two billion by 2050 [4]. Disabilities are more than a health problem, as they affect social and economic

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aspects of people's lives as well. People with disabilities have similar needs as non-disabled people, and they therefore must have opportunities to participate in activities that promote their growth, development, fulfilment, and community contribution.

In an effort to make Web content more accessible, the World Wide Web Consortium (W3C) established the Web Accessibility Initiative (WAI) in 1997. Subsequently, WAI has developed the Authoring Tool Accessibility Guidelines (ATAG) and the Web Content Accessibility Guidelines (WCAG). ATAG represent a set of guidelines for developing accessible authoring tools and, as such, are primarily intended for developers of said tools. Similarly, the WCAG establish criteria for making Web content accessible for people with disabilities and are primarily intended for Web-content creators.

With that in mind, this study examines potential barriers to accessing and producing content. In particular, the study evaluates the accessibility of four popular free open-source authoring tools based on the ATAG 2.0 recommendations. Additionally, it evaluates the accessibility of the educational content generated through them based on the WCAG 2.1 recommendations. The authoring tools included in the study were chosen through a survey applied to in-service teachers. The authoring tools and their generated content were manually evaluated using the ATAG 2.0 and the WCAG 2.1 accessibility evaluation templates. Finally, based on the findings of the study, we establish a set of recommendations for developers, teachers, and students to help close some identified gaps regarding accessibility.

The remainder of this paper is structured as follows. Section 2 analyses previous related work. Section 3 explains the method used to carry out the study. Section 4 analyses the main results of the study. Section 5 presents the main conclusions. Lastly, Sect. 6 presents the limitations of the study and offers some suggestions for future research.

2 Literature review

2.1 Background

Accessibility is defined as the degree to which a person with some type of disability can use a product equivalently to how a person without that disability would use it [4]. In an ICT-mediated environment, Web accessibility refers to a website's ability to be accessed by all types of users, regardless of their limitations [5]. To make a website accessible to a large majority of people, regardless of whether they have a limitation or not, three aspects must be considered: first, generated Web content; second, user agent accessibility (browsers and assistive technologies); and, third, authoring tools that permit creating and publishing content on the Web [6]. Our study focuses on the analysis of the accessibility of authoring tools, as well as the content they generate, to make recommendations for their improvement and best practices.

Regarding the accessibility of authoring tools, the ATAG 2.0 are the most widespread recommendations [6]. This W3C standard is divided into two sections Part A and Part B. Part A provides guidelines for making authoring tools more accessible for authors with disabilities. Part B then provides guidelines that manage how these tools are designed to support the production of Web content which is accessible to a large majority of users [7].

In terms of the accessibility of Web content, the WCAG recommendations have become the leading standard worldwide [6]. This standard seeks to guarantee universal access to people with disabilities through accessible formats and media. The WCAG explain how to make content accessible on the Web, ensuring that most people can understand it and use it considering 13 guidelines organised under 4 principles known as POUR [8]:

- *Perceivable* users must be able to perceive the information being presented on the Web;
- *Operable* users must be able to operate the Web interfaces;
- *Understandable* users must be able to understand the information and the operation of the Web interfaces;
- *Robust* users must be able to access the content.

For each guideline, three levels of success criteria are inspected: A, AA, and AAA. Success criteria describe what content features should be met to accomplish the standard. Level A includes the easiest criteria to meet without much impact on the web design or structure; level AA includes more commitment criteria and level AAA contains more strict criteria. However, level AAA conformance is not required by many legislations around the world because the general requirement is that web sites meet level AA.

WCAG are recommended for Web-content creators and developers of authoring tools. These guidelines have evolved since WCAG 1.0, with their first version published in 1993. The most recent version of this standard (WCAG 2.2) was released in 2021. However, we used the WCAG 2.1 version as the reference for this study, as it was the latest stable version when we conducted the research [8].

2.2 Related work

The adoption of accessibility standards presents some challenges in educational settings, such as cost and increased workload for teachers and designers [9]. As a result, there is a growing number of non-accessible educational resources in educational repositories [10]. It is important to note that accessible educational resources

benefit disabled and non-disabled students alike [11]. For example, transcription and closed captioning of online videos were originally used to make content accessible to the deaf and hard of hearing. However, nowadays, this technology is successfully employed and enjoyed by other groups, such as people who want to learn a second language, people with dyslexia, and seniors [12].

Several studies have analysed different authoring tools and the educational content they generate, identifying some of their most important accessibility barriers. The study by Schiavone [13] presented a systematic literature review on the accessibility of the learning management system (LMS) Moodle. The research included 12 studies published between 2011 and 2017 that focused on Moodle's accessibility. The evaluation included the criteria of the ATAG 2.0. Specifically, the review focused on three lines of research: an accessibility evaluation of Moodle, a comparison of Moodle's accessibility with that of other LMSs, and an analysis of customised solutions based on Moodle. Additionally, to identify the accessibility of the content generated through the system, the research analysed three educational resources designed with Moodle. The analysis was performed under the standards of the WCAG 2.0 and included five Web pages in each educational resource. The authors highlighted that all Web pages presented accessibility issues, with an average of 37 errors per page, according to the evaluated criteria. Therefore, the authors concluded that, despite the improvements made over the years, Moodle cannot be considered a fully accessible LMS and does not allow fully accessible Web content to be developed. However, the study argued that, out of all popular LMSs, Moodle is still the most accessible.

The systematic review by Zhang et al. [14] reviewed 31 papers to assess the accessibility of Open Educational Resources (OER) according to the WCAG 2.0 standards. The authors defined OER as 'teaching, learning, and research materials in any medium that may be composed of copyrightable materials released under an open license, materials not protected by copyright, materials for which copyright protection has expired, or a combination of the foregoing'. The study inspected the OER according to the POUR principles. The results indicated that, out of the four accessibility principles, robust has the highest percentage of errors. Therefore, the authors posited that developers should focus more on OER's compatibility with most assistive devices, as well as with operating systems such as Windows, Mac OSX, and Linux. Finally, the authors concluded that most OER accessibility issues are the result of a lack of inclusive authoring tools, as most OER are created by teachers using these development tools. Hence, the study recommended encouraging developers to attend to and address the accessibility of the authoring tools so as to improve OER's accessibility.

Authoring tool accessibility has been analysed in different studies. Pascual, López, and Granollers [15] described accessibility issues in four embedded Web editors: TinyMCE, KUPU, FCKeditor, and RTE. The authors did not provide information regarding the evaluation methods, but they did describe their findings that emerged from the evaluation of ATAG 2.0 criteria, such as the generation of extra code, tables, images, and multimedia content. Concretely, FCKeditor generates extra code; it does not allow adding headers, rows, and columns in the tables; and it does not support a function to add alternative text to multimedia content. All Web editors showed accessibility issues in the creation and editing of content. This meant VLEs using these editors inherit the accessibility problems of these tools. The same study included the evaluation of three authoring tools—Blogger, Open CMS, and Mediawiki—carried out using the accessibility evaluation framework defined by the authors. The framework included planning the evaluation, a manual evaluation based on WCAG 2.0, and the generation of a report. The results show that the tools' interfaces cannot be configured so that people with disabilities can work on them, and administrators cannot configure or force accessibility features in the editors, among other issues. The methodology used by this study shares elements with the one defined in our study, and Blogger is a tool inspected in both studies.

The study by Bittar et al. [16] selected five authoring tools for coding (Adobe Dreamweaver, Eclipse-Helios, Netbeans 7.1, NVU 1.0, and Microsoft Expression Web 4) to perform a manual accessibility evaluation of selected features in compliance with the ATAG 1.0 and WCAG 2.0 recommendations. As a result, most of the tools do not respect the purpose of the hyperlinks, which means it is possible to insert links that do not redirect to the expected page (except Adobe Dreamweaver). On the other hand, only two tools present accessibility documentation in an integrated manner (Adobe Dreamweaver and Microsoft Expression Web 4). The methodology followed by this study is similar to the one defined in our study.

Pascual, Ribera, and Granollers [17] presented an accessibility evaluation of two popular tools for online blogs—Blogger and WordPress—in compliance with ATAG 1.0 and WCAG 1.0. Although the method was not described, it can be presumed that the authors conducted a hands-on evaluation. The evaluation determined that neither of the two authoring tools correctly completed the priority-1 requirements of the standards used to evaluate them, showing a high percentage of failed checkpoints.

Roig and Ribera [18] presented an evaluation of the conversion of documents from office to the EPUB format, following the ATAG 2.0 guidelines. EPUB is an inclusive format, whose use has been encouraged by the United Nations as a strategy to address accessibility. The study followed

a three-step procedure: First, the selection of author tools, second, the selection of the elements to analyse, and third, the creation of elements with every selected tool. The authors highlighted the low adoption of the EPUB format by researchers. Additionally, the findings indicate that the quality of the conversion is not acceptable in terms of accessibility, making it impractical to create EPUB documents by non-technical users.

Finally, Avila's et al. research [19] provided a model for creating and evaluating inclusive and accessible open educational resources. As for the evaluation process, the model proposed a peer-to-peer hands-on assessment of the resources. This evaluation is conducted in two phases: The evaluation of the accessibility and the evaluation of the quality. The evaluation instrument for accessibility is based on the ATAG 2.0 guidelines. This instrument includes 21 questions organised in 8 categories that assess accessibility and represents the bases for the instrument that we designed for this study.

In this paper, we extend the research on the accessibility of authoring tools and the content they generate. Following the previous studies and the recommendations by in-service teachers, we analyse four popular authoring tools: Hot Potatoes, JClic, ATutor (TinyMCE), and Blogger. According to our review of existing literature, TinyMCE and Blogger have been previously analysed, while Hot Potatoes and JClic have not.

Another contribution of this paper is the consideration of the most stable versions of the WAI guidelines: ATAG 2.0 and WCAG 2.1. To conclude, we offer some recommendations for teachers, developers, and students aiming to improve the accessibility of educational resources.

3 Method

The study focused on the Colombian educational system. We identified the most popular authoring tools in Colombia and subsequently evaluated some educational resources produced and used in that country. Based on the studies by Bittar et al. [16], Avila et al. [19], and Roig and Ribera [18], we manually assessed the accessibility of four authoring tools in reference to the ATAG 2.0 and WCAG 2.1 standards. We followed a mixed methodological design with a descriptive scope consisting of the following four stages: (1) selection of the authoring tools, (2) OER selection, (3) evaluation of compliance with ATAG 2.0 and WCAG 2.1, and (4) recommendations for stakeholders. Each of the stages is described in more detail in the following subsections. The documentation that supports our study is available in full at the Project documentation repository [https://osf.io/srvbc/?view_only=d44d88cd3bc641f0a15c24f75df12117].

4 Selection of the authoring tools

We created a survey to obtain primary data on what authoring tools are most frequently used by Colombian teachers. Our process was as follows:

- *Survey design* We designed a questionnaire for online data collection. Its main purpose was the identification of authoring tools used by Colombian teachers for the creation of Web content for educational purposes. The survey is available in the project documentation repository;
- *Publishing the survey online* The survey was designed and published on the Survey Monkey® platform;
- *Selecting the sample* We invited 69 Colombian teachers to participate in the research process;
- *Applying the survey* 22 teachers completed the survey in its entirety and signed an informed consent authorising us to use the survey data for academic purposes. The rest of the teachers did not accept the invitation or did not complete the survey. Informed consent forms are available in the project documentation repository;
- *Selection of the authoring tools* Based on the results of the survey, four authoring tools were selected to be evaluated in this study.

The survey was conducted during the second semester of 2019.

4.1 OER selection

To evaluate the accessibility of the selected authoring tools and the educational content generated through them, we identified four educational resources available on the free-access platform Colombia Aprende of the Colombian Ministry of National Education [20]. The Colombia Aprende portal is an initiative of the Colombian Ministry of Education and is the largest repository of educational content in the country. It focuses on open access to quality content created by and for the educational community, with an organisational structure that guarantees the suitability of the published digital entities. The search on this portal was performed on December 23, 2019. We searched for the subjects 'solar system' and 'space', two common topics in primary education. The search yielded three resources for 'solar system' and two for 'space.'

Out of these five educational resources, two were selected for this study. The procedure for the selection was as follows:

- *General review of the OER* The educational resource was reviewed, confirming its completeness, structure, and theme;

- *Review of copyright* The copyright of the OER was verified. Specifically, we verified that the contents were shared under a Creative Commons Attribution-NonCommercial-ShareAlike International License (CC BY-NC-SA);
- *Downloading digital resources* The content package of the OER was downloaded as a digital file in the ZIP format.

4.2 Evaluation of compliance with ATAG 2.0 and WCAG 2.1

The evaluation stage consisted of three components: the definition of the criteria to be evaluated, the definition of the evaluation instruments, and the evaluation process itself. We defined the criteria according to the purpose of the study, based on the ATAG 2.0 and WCAG 2.1 standards. Subsequently, we defined the evaluation instruments, which consisted of three templates derived from the official documents by the W3C: first, the Declaration of Conformity template; second, the WCAG 2.1 accessibility evaluation template; and third, the ATAG 2.0 accessibility evaluation template. We used Google Chrome 62.0.3202.94 and Firefox Quantum 57.0.4 under Windows 10 Home for the inspection. Additionally, for supporting the inspection, we used the following tools:

- NVDA (Non-Visual Desktop Access), a screen reader that reads, by means of text-speech, all the contents presented to the user, including text elements, tables, forms and others. In our study, NVDA supported the identification of the most common obstacles screen reader users could face using the OER, helping to overcome them;
- Web Accessibility Checker (AChecker), Online Service, allowed us to carry out an automatic accessibility evaluation of the OER according to specific accessibility guidelines, identifying known, potential and likely problems of accessibility in the OER;
- Web Accessibility Tool (WAVE), another automatic accessibility evaluation tool that allows to identify many accessibility errors based on WCAG 2.1.WAVE also support accessibility human evaluation;
- Colour Contrast Analyzer (CCA), a tool that allows to identify contrast problems in contents;
- Photosensitive Epilepsy Analysis Tool (PEAT) that allows to identify elements that could produce seizures in people with photosensitive seizure disorders;
- Markup Validation Service W3C, an online tool provided by the W3C to check markup validity.

We provide an extended description of those tools in the wiki of the project documentation repository. Finally, we proceeded with the evaluation process by manually inspecting each authoring tool, supporting the inspection on some software tools for automated testing.

Two evaluators were involved in the evaluation process. They work in two different universities and do not have any relationship with the organisations supporting the tools under evaluation, ensuring the independence and impartiality of the evaluation presented in this paper. Both evaluators have experience in evaluating Web accessibility in contents and tools as well as expertise using the evaluation tools mentioned before. Each evaluator conducted the evaluation separately. At the end of the evaluation, the evaluators gathered to review and analyse their results. Occasional differences were solved through consensus.

5 Results

The results are presented in terms of the selected authoring tools, the selected OER, the accessibility evaluation performed, and the designed recommendations for stakeholders.

5.1 Selected authoring tools

Ninety-five per cent of the in-service teachers had a master's degree and 5% had a bachelor's degree. Participants set a balanced sample of 45.45% men and 54.55% women. They work in different and diverse regions in Colombia, as shown in Fig. 1.

Teachers participating in the study teach in areas like math, science, environmental care, language, and informatics, among others. They indicated that it is crucial to use ICT in teaching and learning processes; 36% always integrate ICT-mediated educational resources at school, while 41% do so occasionally. Furthermore, 55% of the teachers have mastered tools for the creation of multimedia content.

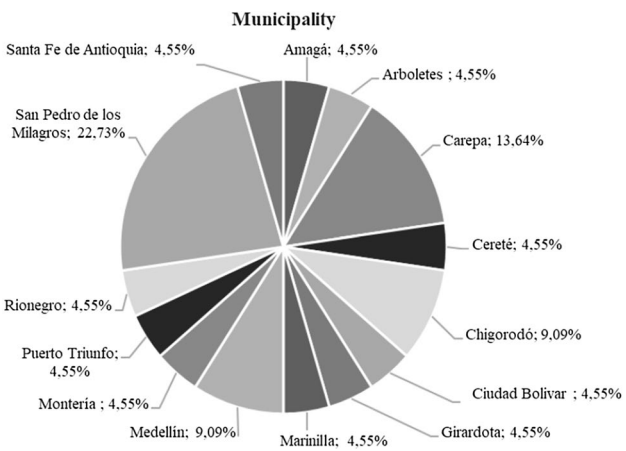

Fig. 1 Sample regions

Table 1 Authoring tools known by teachers

Authoring tools embedded on VLE (Known)	Frequency (*f*)	% (*f*/Total)
Moodle	20	37.74
ATutor	19	35.85
Sakai	3	5.66
Chamilo	3	5.66
Blackboard	2	3.77
Other	6	11.32
None	0	0.00
Total	53	100

Table 2 Authoring tools used by teachers

Authoring tools embedded on VLE (Used)	Frequency (*f*)	% (*f*/Total)
Moodle	20	44.44
ATutor	17	37.78
Sakai	1	2.22
Chamilo	0	0.00
Blackboard	0	0.00
Other	7	15.56
None	0	0.00
Total	45	100

Table 3 IAT known by teachers

IAT (Known)	Frequency (*f*)	% (*f*/Total)
Hot Potatoes	9	10.47
JClic	12	13.95
eXeLearning	9	10.47
Edmodo	18	20.93
WordPress	12	13.95
Blogger	22	25.58
Other	4	4.65
Total	86	100

We consider two kinds of authoring tools: authoring tools embedded in virtual learning environments and independent authoring tools (IAT).

Table 1 shows the results for the authoring tools embedded on VLE that most participants know, highlighting Moodle (37.74%) and ATutor (35.85%) (see Table 1).

Similarly, Table 2 shows that the authoring tools embedded on VLE most frequently used by teachers are also Moodle (44.44%) and ATutor (37.78%) (see Table 2).

Regarding the IAT, Table 3 shows the results for the applications teachers have heard about the most, EdModo (20.93%), Blogger (25.58%), JClic (13.95%), and HotPotatoes (10.47%).

Table 4 IAT used by teachers

IAT (Used)	Frequency (*f*)	% (*f*/Total)
Hot Potatoes	7	11.48
JClic	11	18.03
eXeLearning	5	8.20
Edmodo	11	18.03
WordPress	3	4.92
Blogger	21	34.43
Other	3	4.92
Total	61	100

Table 5 Rubric to define the levels of compliance of attribute A1

Level	Description
High	At least 30% of the respondents use the tool
Average	At least 10% of the respondents use the tool
Low	Less than 5% of the respondents use the tool
Null	Respondents do not use the tool

Moreover, around 34.00% of the teachers selected Blogger as their most frequently used application, followed by EdModo (18.03%), JClic (18.03%), and HotPotatoes (11.48%), as shown in Table 4.

In order to select the authoring tools to be evaluated, six attributes and four levels of compliance were defined. These attributes are described as follows:

- *A1* Used by respondents;
- *A2* Open Source and Free;
- *A3* Uses e-Learning standards;
- *A4* Don't need to know HTML;
- *A5* Provides Tutorials;
- *A6* Viewable in Chrome/Firefox.

The levels of compliance to evaluate each of the defined attributes were high, average, low, and null. These values represent the level of intensity and were used to represent the degree of intensity of each attribute:

- *High (H)* high level of compliance (5);
- *Average (A)* average level of compliance (3);
- *Low (L)* Low level of compliance (1);
- *Null (N)* null (lowest) level of compliance (0).

A rubric was defined to facilitate decisions regarding the levels of compliance of each attribute. As an example, Table 5 shows the rubric to define the levels of compliance of attribute A1.

Table 6 Evaluation of AT embedded on VLE

Attributes of AT embedded on VLE	HA1	HA2	HA3	HA4	HA5	HA6
A1	5	1	1	5	1	1
A2	5	5	5	5	3	5
A3	5	0	0	5	5	5
A4	5	1	5	5	5	5
A5	5	3	5	5	5	5
A6	5	5	5	5	5	5
Total	30	15	21	30	24	26

Table 7 Evaluation of IAT

Attributes of IAT	H1	H2	H3	H4	H5	H6	H7	H8	H9
A1	5	1	3	1	3	3	3	1	1
A2	5	5	5	3	5	5	5	5	5
A3	1	3	0	1	5	5	3	0	0
A4	5	5	5	5	5	5	5	1	5
A5	5	3	5	5	5	5	5	5	5
A6	5	5	5	5	5	5	5	5	5
Total	26	22	23	20	28	28	28	17	21

HA1: ATutor; HA2: Khan Academy; HA3: Metaportal; HA4: Moodle; HA5: NEO LMS; HA6: Sakai; H1: Blogger; H2: Edilim; H3: Edmodo; H4: Educaplay; H5: exeLearing; H6: HotPotatoes; H7: JClic; H8: Scratch; H9: WordPress

Table 8 Assessment synthesis

AT embedded on VLE	Score
ATutor	30
Moodle	30
Sakai	26
NEO LMS	24
Metaportal	21
Khan Academy	15

Table 9 Assessment synthesis

IAT	Score
HotPotatoes	28
exeLearning	28
Blogger	26
JClic	26
Edmodo	23
Edilim	22
WordPress	21
Educaplay	20
Scratch	17

Table 6 shows the attribute evaluation for selecting the AT embedded on VLE and Table 7 for the IAT.

Table 8 shows the total score obtained by each AT embedded on VLE.

Table 9 shows the total score obtained by each IAT.

The selected tools were: (1) ATutor (specifically, we evaluated the embedded TinyMCE editor), (2) HotPotatoes, (3) Blogger, and (4) JClic. Although Moodle and exeLearning were not included in the study, they use the embedded TinyMCE editor. The following paragraphs describe each selected authoring tool.

TinyMCE is a WYSIWYG HTML editor for content creation developed by Tiny Technologies Inc. [21]. TinyMCE makes educational content creation easy for teachers and other creators.

Hot Potatoes [22] is a suite of authoring tools created by Half-Baked Software Inc. and the University of Victoria Humanities Computing and Media Centre. The suite includes six applications to create interactive multiple-choice, short-answer, jumbled-sentence, crossword, matching/ordering, and gap-fill exercises for use on the Web. Educational content created with HotPotatoes could be easily integrated on Web pages from VLE.

Blogger [23] is a free service for self-expression and communication owned by Google. In particular, Blogger allows users to create blogs focused on one or multiple topics. Teachers frequently use blogs to communicate with their students.

JClic [24] is a set of free software applications with the GNU GPL license used to create educational activities such as puzzles, associations, text exercises, crosswords, word

searches, etc. It was developed on the Java platform and is supported by the Generalitat de Cataluña.

5.2 Selected OER

The OER from the Colombia Aprende portal were:

- Why has human beings' technology evolved to allow us to go into space? Reproduced in ATutor and Blogger
  (Available at https://colombiaaprende.edu.co/contenidos-para-aprender/por-que-ha-evolucionado-la-tecnologia-del-ser-humano-hasta-permitirle)
- What do the planets of the solar system look like when viewed from space and from Earth? Reproduced in HotPotatoes and JClic.
  (Available at https://colombiaaprende.edu.co/contenidos-para-aprender/como-se-ven-los-planetas-del-sistema-solar-cuando-se-ven-desde-el-espacio).

The OER downloaded from the Colombia Aprende portal did not comply with the SCORM or IMS-CP standards. Therefore, they could not be deployed or reused directly in the authoring tools that comply with these interoperability and re-distribution functionalities.

As permitted by their licensing, the contents were downloaded and reproduced in the selected authoring tools, reusing, adapting, and/or modifying the content for use in this investigation. As the purpose of this study was to analyse the accessibility of both authoring tools and content, the OER reproduction provided us with an adequate evaluation scenario.

However, while finding OER that cannot be reproduced is a common and undesirable situation when dealing with the content available in Colombia Aprende and within other recognised repositories, it remained important for us to use real-world content for the evaluators to work with. On the other hand, this research can contribute by informing stakeholders about possible solutions to this common issue.

It is important to clarify that the objective of this study was not to evaluate the competencies exhibited in creating accessible Web content by the creator or content designer. Instead, the study aims to evaluate the accessibility of the tools and the generated Web content. Therefore, we guaranteed that the creator of the contents had the necessary competencies both in the use of the tool and in Web accessibility.

5.3 Evaluation process

The evaluation was conducted to assess the accessibility of the selected authoring tools based on the ATAG 2.0 and WCAG 2.1 standards. In the following section, we define the criteria under evaluation and describe the results of the accessibility evaluation.

5.3.1 Criteria to evaluate

Based on the study by Avila et al. [19], we defined 12 general criteria which inspect the most important features teachers should look for when producing accessible content, five of which were also considered in the study by Roig and Rivera [18]. Table 10 presents and codes the 12 criteria to be evaluated based on the WCAG 2.1. For the selection of the WCAG criteria, the evaluation is based on the conformance level AA, meaning the AAA criteria were not included. Moreover, those criteria related to input information or forms were not included due to the OER selected not having that kind of components. On the other hand, Table 11 presents the five criteria from ATAG 2.0 to be inspected on the authoring tools. These five criteria were defined based on the most important features that allow those with disabilities to use an authoring tool.

According to the results shown in Table 12 and Table 13, we conclude that:

- TinyMCE (embedded text editor of ATutor) complies with the criteria evaluated. However, it only partially satisfies the requirement of contrast between the non-text content in its interface (e.g. buttons) and the adjacent colours;
- HotPotatoes does not use the higher-level header when auto-generating content (H1). Additionally, it does not have an interface that helps the content producer to create lists (numbered and unnumbered). For tables, although it allows entering the HTML code, this is not helpful for users who are not proficient in a programming language. Thus, this criterion becomes a barrier for a large majority of content creators;
- Blogger presents difficulties in the self-generated content because the links (hyperlinks) cannot be modified to present accessible features, such as purpose and significant description. It also does not support the production of accessible tables, and digital resources cannot be inserted in an audio format;
- JClic is a tool with many functions; however, it only allows editing text font and only partially helps the user to add a multimedia resource. It does not provide any support with respect to any of the other criteria we evaluated. Perhaps its most significant barrier is that it fails to provide alternative text for images. Also, it does not allow for the creation of levels of headings, lists, or accessible tables. Regarding the Web content generated, this issue is even more evident; for example, the links (hyperlinks) are not differentiated from the reading text.

The most common problems between the four tools are:

Table 10 Definition of the criteria to be evaluated (WCAG 2.1)

Code	Element	Guideline/Criterion	Specific criterion
C1	Text Format	1.4.4Resize text 1.4.12 Text Spacing	Using standard text formatting conventions for paragraphs
C2	Headings	1.3.1 Info and Relationships 2.4.6 Headings and Labels	Providing descriptive headings Using H1–H6 to identify headings Using standard text formatting conventions for headings
C3	Navigation	1.3.2 Meaningful Sequence 1.3.3 Sensory Characteristics 2.1.1 Keyboard 2.1.2 No Keyboard Trap 2.1.4 Character Key Shortcuts 2.4.1 Bypass Blocks 2.4.2 Page Titled 2.4.4 Link Purpose (In Context) 2.4.5 Multiple Ways 3.2.3 Consistent Navigation 3.2.4 Consistent Identification	Keeping meaningful sequence Avoiding conveying information or instructions based on sensory characteristics Identifying the purpose of links combined with the enclosed list item Identifying the purpose of a link using link text combined with its enclosing paragraph
C4	Images	1.1.1 Non-Text Content 1.4.5 Images of Text	Providing short text alternatives that provide a brief description of the non-text content
C5	Lists of Elements	1.3.1Info and Relationships	Standard text-formatting conventions for lists Using ol, ul, and dl for lists
C6		1.3.1 Info and Relationships	Using caption elements to associate data table captions with data tables Using table markup to present information
C7	Audio and Video	1.1.1 Non-Text Content 1.2.1Audio-Only and Video-Only (Prerecorded) 1.2.2 Captions (Prerecorded) 1.2.3 Audio Description or Media Alternative (Prerecorded) 1.2.4 Captions (Live) 1.2.5 Audio Description (Prerecorded) 1.4.2 Audio Control	Providing captions for every video un any form (closed or open captions) Providing an alternative for temporary media by linking the alternative to non-text content
C8	Display Orientation	1.3.4 Orientation	Using a control to allow access to content in different orientations
C9	Reflow	1.4.10 eflow	Using CSS flexbox to reflow content Using media queries and grid CSS Allowing for reflow with long URLs and strings of text
C10	Colour and Contrast	1.4.1 Use of Colour 1.4.3 ontrast (Minimum) 1.4.11 Non-Text Contrast	Ensuring the minimum contrast
C11	Focus	1.4.13 Content on Hover or Focus 2.4.3 Focus Order 2.4.7 Focus Visible 3.2.1 On Focus	Available mechanism to dismiss the additional content without moving the hovering pointer Ensuring focus order
C12	Pointer	2.5.1 Pointer Gestures	Providing controls that do not require complex gestures Single-point activation for spatial positioning

- The limited support for creating accessible tables, heading management, or link creation;
- The lack of complete documentation or warning options for checking the Web content generated for compliance with standards such as WCAG.

5.4 Recommendations for stakeholders

Based on the results of the evaluation, we made some recommendations for teachers who support their teaching practice with authoring tools, for authoring tools developers, and for students who consume the educational resources.

5.4.1 Recommendations for teachers

Perhaps the most important recommendation for teachers is being aware of the need to offer an inclusive education that takes into consideration all students and their needs. However, guaranteeing equal opportunities for all students entails several important actions and decisions. First, an

Table 11 Definition of the criteria to be evaluated (ATAG 2.0)

Code	Element	Guideline/Criterion	Specific criterion
C13	Accessibility Support	B.3.1.1. Checking Assistance	Authors are supported in discovering Web content accessibility problems in the content that they are editing
C14	Documentation	B.4.2.2. Feature Instructions	Instructions for using any accessible content support features appear in the documentation
C15	Search	A.3.5.1. Text Search	If the authoring tool provides an editing-view of text-based content, then the editing-view enables text search
C16	Reversible Edits	A.4.1.1. Content Changes Reversible (Minimum)	Text entry actions can be reversed using 'Undo' and 'Redo' features
C17	Accessible Interface	A.1.1.1. Web-Based Accessible (WCAG) A.1.2.1. Accessibility Guidelines	User interfaces meet the WCAG 2.0 success criteria (Level AA)

Table 12 Criteria evaluation WCAG 2.1

	Element	TinyMCE	HotPotatoes	Blogger	JClic
C1	Text Format				
C2	Headings		×		×
C3	Navigation			Θ	×
C4	Images				×
C5	Lists of Elements		×		×
C6			×	×	×
C7	Audio and Video			Θ	Θ
C8	Display Orientation				
C9	Reflow		×		
C10	Colour and Contrast	Θ		Θ	×
C11	Focus				
C12	Pointer				

Table 13 Criteria evaluation ATAG 2.0

		TinyMCE	HotPotatoes	Blogger	JClic
C13	Accessibility Support		×	×	×
C14	Documentation		×	×	×
C15	Search		×	×	×
C16	Reversible Edits				×
C17	Accessible Interface		Θ	Θ	×

The codes represent the following: = Attend; × = Did not attend; Θ = Attended partially

educator must select adequate authoring tools to support all students' learning. As demonstrated in this study, authoring tools can—and often do—fail in accomplishing accessibility standards. Second, acquiring abilities for creating accessible content is not only a task for developers but for all teachers committed to offering a high-quality education. Based on both ideas, we encourage teachers to cultivate their own professional development, including technical and pedagogical competencies in the generation of accessible educational content. In particular, they should heed accessibility features in headings, images, tables, links, lists (ordered or not), video and audio, acronyms and abbreviations, colour contrast, and math elements. Moreover, teachers should be aware of the assistive technologies used by their students (screen readers, screen magnifiers, adaptations of keyboards, or others) and how content creation could affect the functionality of those technologies. Finally, faculties should define criteria for selecting the authoring tool used by their staff. Faculties also have the responsibility to disseminate information about discovered accessibility issues, whether voiced by educators or students, to encourage developers to make their products more accessible.

5.4.2 Recommendations for developers

Developers of authoring tools are highly responsible for the accessibility of the content available on the Web. While it is important for developers to understand accessibility standards or recommendations, they should adopt good practices during the whole software development cycle. Accessibility is not a feature to be evaluated after the product has been developed; rather, it is a feature that should be guaranteed from the introductory design stages. Developers should be more in touch with their end-users, involving diverse target groups in requirement definitions, inclusive design, or user-based accessibility testing, ensuring the product fits the need of all potential users.

Particularly, our results indicate some important issues that should be addressed in the tools analysed. Among these tools, there is no support for creating accessible tables (HotPotatoes, Blogger, and JClic), to identify elements for heading levels, or to use numbered and unnumbered lists (HotPotatoes and Blogger). Furthermore, only two authoring tools help developers provide meaningful link text (ATutor and HotPotatoes). Therefore, we advise software developers consider criterion 1.3.1 and criterion 2.4.4 of the WCAG 2.1 standard.

HotPotatoes provides a contrast ratio of at least 3:1 with respect to adjacent colours (background) for non-textual components. The other authoring tools evaluated (ATutor, Blogger, and JClic) allow users to read the published text without having to use double scrolling (reflow) when increasing the text size. Consequently, the adoption of programming techniques and designs should comply with criterion 1.4.11 and criterion 1.4.10 of the WCAG 2.1 standard. On the other hand, it is also evident that HotPotatoes, Blogger, and JClic do not comply with at least level A of the ATAG 2.0. Consequently, we emphasise the need to integrate criterion A.4.2 of the WCAG 2.1 standard in the development of future authoring tools.

Finally, we encourage developers to build an accessibility check tool into the systems included in this study.

5.4.3 Recommendations for students

Students are not only consumers but also producers of content. They should take advantage of technology to learn in a positive way and be active and vocal in letting their teacher know if they are experiencing any barriers to educational content, including barriers detected by other students.

When possible, students should be involved in the content creation process, contributing their experience in the use of technologies unknown by the teacher, helping teachers to take advantage of accessible ICT to support the inclusion of all their partners. If necessary, students should ask for assistive technology that facilitates using and accessing generated educational resources, such as screen readers, screen magnifiers, keyboard adaptations, and others.

6 Conclusions

The development of accessible OER has become a basic means of helping students with special needs. Authoring tools facilitate teachers and designers to create these resources. However, most of them present accessibility barriers and, consequently, should be improved according to widely accepted accessibility standards.

In this study, we evaluated the accessibility of four authoring tools—ATutor, HotPotatoes, Blogger, and JClic—based on the ATAG 2.0 standards. We also evaluated the accessibility of the educational content generated through them based on the WCAG 2.1 standards. As a result, we observed that TinyMCE fulfilled most of the criteria selected in the accessibility evaluation. It is important to mention that only TinyMCE alerts the author to non-compliance with certain accessibility guidelines in the HTML code. The other tools partially satisfied the evaluation criteria, presenting limitations in other criteria described in Sect. 4.3.

Further research is needed to analyse how the authoring tools work on mobile devices, including changing screen sizes and moving from mouse/keyboard to a touch interface and consider the presence of app-based authoring tools for these platforms.

Finally, the COVID pandemic and its consequences, including lockdowns and online schooling, has allowed educational actors to reflect on the importance of full access to virtual education for all, including teachers and students with diverse needs. Inclusion implies encouraging developers to consider accessibility when creating authoring tools and empowering content creators to develop accessible educational content.

7 Limitations and future work

The results of the study can be used as a guide, providing some recommendations to fill vital research gaps around the creation of accessible authoring tools and educational content. However, there are important limitations that must be considered when interpreting the results.

The study analysed four authoring tools popular in Colombia. The scope of the study is thus limited to the Colombian use case. Therefore, to improve the analysis of the accessibility of authoring tools, future research must include other authoring tools used in other countries. Additionally, the sample of the survey used to select the authoring tools included only 22 teachers. Therefore, the study can be improved by using a larger sample of teachers to identify the most widely used authoring tools.

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Data availability The documentation that supports our study is available at https://osf.io/srvbc/?view_only=d44d88cd3bc641f0a15c24f75df12117.

Code availability Not applicable.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Fauville, G., Lantz-Andersson, A., Säljö, R.: ICT tools in environmental education: reviewing two newcomers to schools. Environ. Educ. Res. **20**(2), 248–283 (2014). https://doi.org/10.1080/13504622.2013.775220

2. Asgari, S., Mehrpouyan, A.: A group comparison of E-learning authoring tools in educational production and management. Indian J. Sci. Technol. **11**, 24 (2018)
3. Treviranus, J., Richards, J., Clark, C.: Inclusively Designed Authoring Tools. In: Yesilada, Y., Harper, S. (eds.) Web Accessibility. Human-Computer Interaction Series, pp. 357–372. Springer, London (2019)
4. WHO: Disability and health, Geneva (2018)
5. Cooper, M.: Web accessibility guidelines for the 2020s. In: Proceedings of the 13th Web for All Conference, pp. 1–4 (2016)
6. Acosta-Vargas, P., Acosta, T., Lujan-Mora, S.: Challenges to assess accessibility in higher education websites: a comparative study of Latin america universities. IEEE Access **6**, 36500–36508 (2018). https://doi.org/10.1109/ACCESS.2018.2848978
7. W3C: Authoring Tools Accessibility Guidelines (ATAG) Overview (2015)
8. W3C: Web Content Accessibility Guidelines 2.1 (2018)
9. Kurt, S.: Moving toward a universally accessible web: Web accessibility and education. Assist. Technol. **31**(4), 199–208 (2019). https://doi.org/10.1080/10400435.2017.1414086
10. Rodrigo, C., Tabuenca, B.: Ecologías de aprendizaje en estudiantes online con discapacidades. Comunicar **28**(62), 53–65 (2020). https://doi.org/10.3916/C62-2020-05
11. Moriña, A.: Inclusive education in higher education: challenges and opportunities. Eur. J. Spec. Needs Educ. **32**(1), 3–17 (2017)
12. Mourão, A.B., Netto, J.F.D.M.: Inclusive model application using accessible learning objects to support the teaching of mathematics. Informatics Educ. **18**(1), 213–226 (2019). https://doi.org/10.15388/infedu.2019.10
13. Schiavone, A.: Is Moodle accessible? An analysis through experiences in scientific literature and a case study. In: International Symposium on the Future of Education in Information Science, pp. 165–174 (2018).
14. Zhang, X., et al.: Accessibility within open educational resources and practices for disabled learners: a systematic literature review. Smart Learn. Environ. **7**(1), 1–19 (2020). https://doi.org/10.1186/s40561-019-0113-2
15. Pascual, A., López, J.M., Granollers, T.: Aportaciones a la mejora de la evaluación de la accesibilidad en entornos web 2.0 interactivos administrados mediante sistemas de gestión de contenido, Universitat de Lleida (2009)
16. Bittar, T.J., do Amaral, L.A., Faria, F.B., de Mattos Fortes, R.P.: Supporting the developer in an accessible edition of web communications. In: Proceedings of Working Information in System Design Communication-ISDOC '12, pp. 3–9 (2012). https://doi.org/10.1145/2311917.2311919
17. Pascual, A., Ribera, M., Granollers, T.: In Proceedings of the 13th International Conference on Interacción Persona-Ordenador (INTERACCION'12). In: Perception of accessibility errors to raise awareness among web 2.0 users (2012). https://doi.org/10.1145/2379636.2379652
18. Roig, J., Ribera, M.: Creation of accessible EPUB documents by non-technical users. In: Proceedings of the XXI International Conference on Human Computer Interaction-Interacción '15, vol. 1, no. 1, pp. 1–2 (2015). https://doi.org/10.1145/2829875.2829926
19. Avila, C., Baldiris, S., Fabregat, R., Graf, S.: Cocreation and evaluation of inclusive and accessible open educational resources: a mapping toward the IMS caliper. IEEE Rev. Iberoam. Tecnol. del Aprendiz. **11**(3), 167–176 (2016). https://doi.org/10.1109/RITA.2016.2589578
20. Ministry of National Education: Portal Colombia Aprende - Banco de Contenidos (2018)
21. TinyMCE: TinyMCE Editor (2021). https://www.tiny.cloud/. Accessed 30 Dec 2021
22. Half-baked softare Inc: Hot Potatoes (2009). https://hotpot.uvic.ca/. Accessed 30 Dec 2021
23. Google: Blogger (2021). https://www.blogger.com/about/. Accessed 30 Dec 2021
24. Xarxa Telemàtica Educativa de Catalunya: JClic (1992). https://clic.xtec.cat/legacy/es/jclic/. Accessed 30 Dec 2021