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# Empirical Studies on Web Accessibility of Educational Websites: A Systematic Literature Review

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**ABSTRACT** Web accessibility means that people with some type of disability can make use of the Web in the same conditions as the rest of the people. When we talk about web accessibility, we refer to a web design and development that allows these people to perceive, understand, navigate and interact with the Web. Web accessibility also benefits other people, including elderly people whose abilities have declined as a result of age. The Web is an essential resource in human activity: education, employment, government, commerce, health, entertainment and many others benefit of the power of the Web. The aim of this systematic literature review is to analyze the empirical methods of evaluating accessibility to educational websites, disabilities and their errors described in a total of 25 selected studies. The results show that in 20 of the 25 papers, web accessibility was evaluated with automatic tools, in 2 papers it was evaluated with real users and in the other 3 papers with automatic tools, real users and experts. There is also evidence that all the educational websites analyzed in the papers need to correct errors. In conclusion, educational websites do not meet any version of the Web Content Accessibility Guidelines (WCAG) and their conformance levels. According to the results, the empirical evaluation methods used for web accessibility could be improved by adopting automatic evaluation tools for website construction and manual mechanisms with web accessibility experts. The challenge for educational institutions is to carry out web accessibility projects to comply with WCAG and other web accessibility standards and current laws of educational inclusion.

**INDEX TERMS** Assessment, education, systematic literature review, websites, web page design, Web content accessibility guidelines (WCAG).

## I. INTRODUCTION

The World Wide Web has emerged as the largest information repository and it is one of the most important communication media available [1]. Tim Berners-Lee, Director of the World Wide Web Consortium (W3C) and inventor of the World Wide Web [2], states that ''the power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect'' [3].

W3C has developed Web Content Accessibility Guidelines (WCAG) to make the web accessible to people with disabilities. The WCAG 2.0 was approved as an ISO standard in 2012 [4]. The WCAG 2.1, the latest version of these guidelines, covers a wide range of recommendations for making web content more accessible [5]. Following these guidelines will make content more accessible to a wider range of people with disabilities, including accommodations for blindness and low vision, deafness and hearing loss, limited movement, speech disabilities, photosensitivity, and combinations of these, and some accommodation for learning disabilities and cognitive limitations [5], [6]. People with disabilities can use websites when they are designed and coded appropriately. However, websites with accessibility barriers that make it difficult for people with disabilities to use them continue to be developed. According to the W3C, making the web accessible ''benefits individuals, businesses and society'' [7].

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The Web is an increasingly important resource in many aspects of life: education, employment, government, commerce, health care, recreation, and more. S. L. Henry, who leads worldwide education and outreach activities promoting web accessibility for people with disabilities at the W3C Web Accessibility Initiative (WAI), states that ''it is essential that the Web be accessible in order to provide equal access and equal opportunity to people with diverse abilities and not exclude people from using their products and services'' [7]. The United Nations Convention on the rights of persons with disabilities defines access to information and communication technologies, including the Web, as a basic human right [8]. The Web removes the barriers to communication and interaction that people with and without disabilities face in the physical world [2]. Different versions of the WCAG have been developed to help improve access to and understanding of websites content [9]. However, it is very important that those responsible for educational government entities implement policies for compliance with the WCAG on educational websites. The greatest concern about web accessibility issues comes from the growing dependence of today's businesses and communities on the Internet. This fact has attracted considerable attention from academics around the world to examine and recommend solutions that address web accessibility issues [10].

According to M. Akram and R. Bt Sulaiman [11], educational institutions should have their own website to publish their content, academic and administrative resources, among others. These websites can be used by graduate students, students in training, future students and students' families and so on. Bearing in mind that most universities offer online services to students, such as library consultation, course registration, grades checking and so on. Therefore, educational websites must comply with accessibility standards in order for people or students with disabilities to interact with their content.

The literature review is an essential feature of any academic project: An effective literature review creates a firm foundation for advancing knowledge, facilitates theory development, closes areas where a plethora of research exists, and uncovers areas where research is needed [12]. For this reason, this paper presents a systematic literature review (SLR) that has been conducted to determine its research scope on existing web accessibility evaluation methods with respect to educational websites and to provide a comprehensive overview of solutions and examine new research avenues and opportunities.

Throughout this document, the term ''web accessibility'' is used to determine the assessment and compliance with WCAG 1.0, WCAG 2.0 and WCAG 2.1 on educational websites. In addition, this study will identify the evaluation methods used, accessibility errors, and disabilities addressed in the selected studies.

This study reviews a set of selected papers that evaluate the accessibility of educational websites. Our work focuses on empirical studies as we want to discover whether web accessibility is rigorously evaluated and considered an important issue in education. The aim of this SLR is to analyze the empirical methods of evaluating accessibility to educational websites, disabilities and their errors described in a total of 25 selected studies. We believe it is essential that the SLR methodology is used constructively to support web accessibility research [13].

Since this paper is intended to provide an in-depth study of empirical methods of web accessibility assessment and error analysis related to educational websites, it is divided into the following sections. In Section II, the background of the main web accessibility concepts needed to understand the WCAG, the success criteria and their levels of conformance are presented. In Section III, the methodology used for the SLR is introduced. In Section IV, the results that answer the research questions are presented in two sections. The first Section IV-A Bibliometric Analysis comprises relevant data such as type of journal and number of papers per year. The second Section IV-B Systematic Literature Review presents an analysis of the selected studies. In Section V, the discussion highlights the relevant findings of the SLR study to identify trends and gaps. In Section VI, the limitations of this study are described. Finally, conclusions and future work are presented in the Section VII.

## II. BACKGROUND

This section defines the concept of web accessibility and describes the different versions of WCAG, with its principles, guidelines and levels of conformity. Web accessibility aims to make websites more accessible and usable by as many people as possible, regardless of their knowledge, skills or technical characteristics. W3C worldwide promotes the adoption of web accessibility guidelines through the WAI. In 1999, the WAI published the first version of its WCAG, which have become an international benchmark. WCAG 2.0 was published in December 2008, WCAG 2.1 in June 2018 and the first public draft of WCAG 2.2 in February 2020. WCAG 2.0 became the international standard ISO/IEC 40500:2012 [14]. WCAG 2.1 contains all the success criteria of WCAG 2.0 plus 17 additional success criteria. The European Union [15] adopted WCAG 2.1 in September 2018 as a standard for websites and electronic documents.

The WCAG recommendations help website designers and developers to better meet the needs of users with disabilities and older users. These guidelines are intended for website developers and designers, creators of authoring tools for website design and programming, developers of web accessibility evaluation tools, and anyone who needs a reference standard for checking the accessibility of specific web content. Web accessibility benefits people with and without disabilities and improves the usability of websites.

### A. WEB ACCESSIBILITY

The W3C defines web accessibility as ''essential for developers and organizations that want to create high quality websites and web tools, and not exclude people from using their

products and services'' [2]. The Information technology — Development of user interface accessibility — Part 1: Code of practice for creating accessible ICT products and services, ISO/IEC 30071-1:2019 [16] defines accessibility as the ''extent to which products, systems, services, environments, and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use''. Therefore, web accessibility can be defined as a universal access to the Web [17].

### B. WEB CONTENT ACCESSIBILITY GUIDELINES (WCAG)

WCAG is developed through the W3C process in cooperation with individuals and organizations around the world, with the goal of providing a single shared standard for web content accessibility that meets the needs of individuals, organizations, and governments internationally. The WCAG documents explain how to make web content more accessible to people with disabilities [4].

An overview of the different versions of the WCAG is shown in Table 1. The priorities of WCAG 1.0, its checkpoints and levels of conformity. It also shows the WCAG 2.0 and 2.1 principles with their success criteria and levels of conformity.

In addition to the WCAG that have been formally published in February 2020 [18], a draft of the WCAG 2.2 has been published. The draft WCAG 2.2 extends WCAG 2.1, content that conforms to WCAG 2.2 also conforms to WCAG 2.0 and WCAG 2.1. W3C recommends the use of WCAG 2.2 to maximize the future applicability of accessibility efforts. The W3C also encourages the use of the most recent version of the WCAG when developing or updating web accessibility policies.

### C. WEB CONTENT ACCESSIBILITY GUIDELINES (WCAG) 1.0

WCAG 1.0 [19] has 14 guidelines or general principles of accessible design and 65 checkpoints. The checkpoint definitions in each guideline explain how the guideline applies in typical content development scenarios. Each checkpoint is intended to be specific enough so that someone reviewing a page or site may verify that the checkpoint has been satisfied:

1) Guideline 1. Provide equivalent alternatives to auditory and visual content.
2) Guideline 2. Don't rely on color alone.
3) Guideline 3. Use markup and style sheets and do so properly.
4) Guideline 4. Clarify natural language usage.
5) Guideline 5. Create tables that transform gracefully.
6) Guideline 6. Ensure that pages featuring new technologies transform gracefully.
7) Guideline 7. Ensure user control of time-sensitive content changes.

**TABLE 1. WCAG, priorities and principles, checkpoints and success criteria and levels of conformity.**

| WCAG | Priorities and Principles | Checkpoints and Success Criteria | Levels of conformity |
|---|---|---|---|
| WCAG 1.0 | Priority 1 | 16 | "A": all Priority 1 checkpoints are satisfied. |
| | Priority 2 | 30 | "Double-A": all Priority 1 and 2 checkpoints are satisfied. |
| | Priority 3 | 19 | "Triple-A": all Priority 1, 2, and 3 checkpoints are satisfied. |
| | **Total Checkpoints** | **65** | |
| WCAG 2.0 | | 9 | A |
| | Perceivable: | 5 | AA |
| | 4 guidelines | 8 | AAA |
| | Total: | 22 | |
| | | 9 | A |
| | Operable: | 3 | AA |
| | 4 guidelines | 8 | AAA |
| | Total: | 20 | |
| | | 5 | A |
| | Understandable: | 5 | AA |
| | 3 guidelines | 7 | AAA |
| | Total: | 17 | |
| | | 2 | A |
| | Robust: | 0 | AA |
| | 1 guideline | 0 | AAA |
| | Total: | 2 | |
| | **Total Success Criteria** | **61** | |
| WCAG 2.1 | | 9 | A |
| | Perceivable: | 11 | AA |
| | 4 guidelines | 9 | AAA |
| | Total: | 29 | |
| | | 14 | A |
| | Operable: | 3 | AA |
| | 5 guidelines | 12 | AAA |
| | Total: | 29 | |
| | | 5 | A |
| | Understandable: | 5 | AA |
| | 3 guidelines | 7 | AAA |
| | Total: | 17 | |
| | | 2 | A |
| | Robust: | 1 | AA |
| | 1 guideline | 0 | AAA |
| | Total: | 3 | |
| | **Total Success Criteria** | **78** | |

8) Guideline 8. Ensure direct accessibility of embedded user interfaces.
9) Guideline 9. Design for device-independence.
10) Guideline 10. Use interim solutions.
11) Guideline 11. Use W3C technologies and guidelines.
12) Guideline 12. Provide context and orientation information.
13) Guideline 13. Provide clear navigation mechanisms.
14) Guideline 14. Ensure that documents are clear and simple.

The three levels of conformity defined in WCAG 1.0 are [19]:

- Conformance Level ''A'': all Priority 1 checkpoints are satisfied;
- Conformance Level ''Double-A'': all Priority 1 and 2 checkpoints are satisfied;
- Conformance Level ''Triple-A'': all Priority 1, 2, and 3 checkpoints are satisfied;

### D. WEB CONTENT ACCESSIBILITY GUIDELINES (WCAG) 2.0

WCAG 2.0 [4] has 12 guidelines that are organized under 4 principles: perceivable, operable, understandable, and robust. For each guideline, there are testable success criteria, which are at three levels of conformance A, (25 success criteria), AA (38 success criteria: 25 level A plus 13 level AA) and AAA (61 success criteria: 25 level A, 13 level AA and 23 level AAA).

### E. WEB CONTENT ACCESSIBILITY GUIDELINES (WCAG) 2.1

WCAG 2.1 [5] extends WCAG 2.0 by adding 17 new success criteria, 1 guideline and a couple of additions to the compliance section. This approach means that websites that comply with WCAG 2.1 also comply with WCAG 2.0. WCAG 2.1 [5] has 13 guidelines organized under 4 principles: perceptible, operable, understandable and robust. For each guideline, there are verifiable success criteria, which are at three levels of conformance A (30 success criteria), AA (50 success criteria: 30 level A plus 20 level AA) and AAA (78 success criteria: 30 level A, 20 level AA and 28 level AAA). Figure 1, presents the success criteria, with their levels of conformance for each one of the WCAG 2.1 principles. For a website to be compliant with WCAG 2.1, all compliance requirements must be met.

## III. SYSTEMATIC LITERATURE REVIEW METHODOLOGY

An SLR involves several discrete activities. This section summarises the stages in an SLR into three main phases: Planning the Review, Conducting the Review and Reporting the Review [20].

### A. PLANNING THE SYSTEMATIC LITERATURE REVIEW STUDY

The objectives of this stage are to identify the need for an SLR study and to develop a review protocol.

#### 1) IDENTIFICATION OF NEED FOR A SYSTEMATIC LITERATURE REVIEW STUDY

Based on the suggestions of some papers [20]–[23] we searched for SLRs and similar publications related to web accessibility of educational websites to verify if the SLR proposed in this paper can fill any gaps. For the search we use one search strings for Scopus and one search string for the Web of Science. The search strings used are presented below:

- Scopus: TITLE(systematic education* accessib*) OR TITLE ( literature AND education* AND accessib*) OR TITLE (review AND education* AND accessib*) OR TITLE (survey AND education* AND accessib*)
- Web of Science: (''systematic literature review'' and ''web accessibility'')

We found four SLRs [24]–[27] that have a relationship with ours:

1) In 2016, S. Hernández Otálora, O. Quejada Durán, and G. Díaz [24] carried out a methodological guide for the development of accessible virtual educational environments. This work presents a methodological guide that defines guidelines for the development of accessible virtual learning environments, considering the four dimensions: diagnosis of the accessibility conditions of the different components of the environment, from which it is proposed to plan the actions that each component must carry out in a later implementation stage. A continuous follow-up and control should be carried out to guarantee the fulfilment of the proposed objectives. The authors conclude that this guide focuses on aspects related to accessibility; the different stages should involve all aspects related to the development of a project of this nature. Thus, this guide provides practical tools to achieve that people with disabilities can really access training processes supported by virtual education.
2) In 2017, K. Lee [25] conducted a historical review of the accessibility of online higher education. This was done using two concepts: ''authentic accessibility'' and ''programmatic definition'', each of which examined actual practice. The results highlight the growing multiplicity of practices and realities of online education, and the limitations of typical conceptualizations of these phenomena, which have historically conceptualized distance education as a single domain. The authors conclude that the evidence presented in this historical review article suggests that it is difficult to know the extent to which true accessibility of university education is realized through online higher education and, in doing so, actually weakens popular claims about the accessibility of online higher education. Instead, they have sought to remind academics in the field of online higher education that increasing the accessibility of university education is a complex and

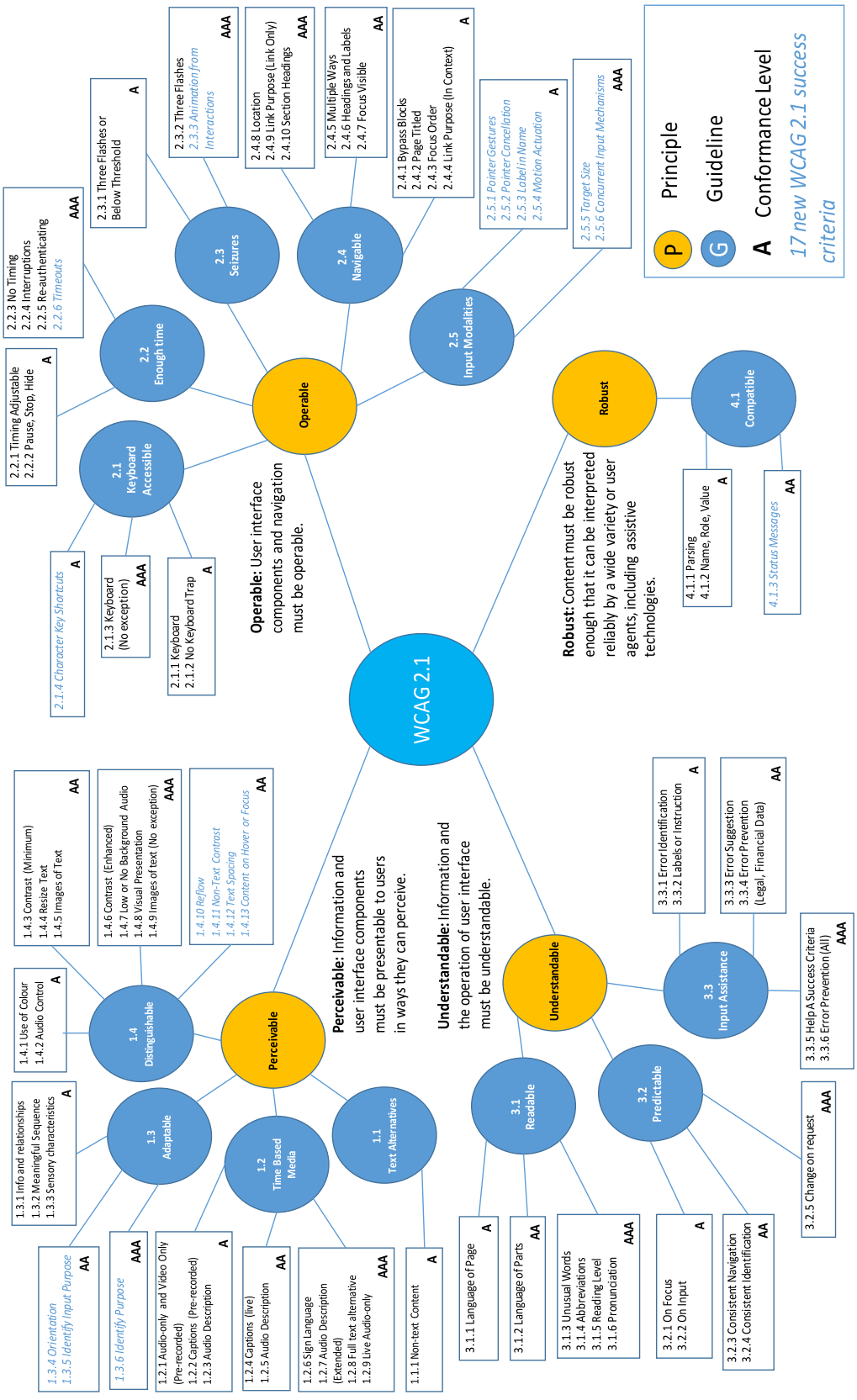


**FIGURE 1.** Web content accessibility guidelines 2.1 map.

multidimensional social issue, requiring serious and ongoing academic discussions.

3) In 2017, M. Akram and R. Bt Sulaiman [26] conducted an SLR on research studies in Saudi Arabia and outside of Saudi Arabia to explore the web accessibility issue in the governmental and university websites. The objective of this study was to review the existing literature to identify the web accessibility issues in Saudi Arabian university and government websites through a systematic literature review. Several scholarly databases were searched for the research studies published on web accessibility evaluation globally and in Saudi Arabia from 2009 to 2017. Only 15 (6 based on Saudi Arabia and 9 global) research articles out of 123 articles fulfilled the selection criteria. Literature review reveals that web accessibility is a global issue and many countries around the world including Saudi Arabia are facing web accessibility challenges. The authors have found that no website is following the World Wide Web consortium's web accessibility guidelines. They also noted that some countries have legislation but still facing web accessibility issue due to not proper implementation of web accessibility law.
4) In 2020 C. M. Baker, Y. N. El-Glaly, and K. Shinohara [27], conducted research on SLR to identify common themes and methods covered in the computer education literature, with a particular focus on how the research seeks to improve ways to integrate accessibility into the computer education curriculum. Despite the general consensus that teaching accessibility in the computer science curriculum is good, there are few tools and resources to support instructors in higher education. At the same time, the literature provides little information on how to introduce these topics into the core curriculum. The authors in the conclusions provide suggestions for the future direction of accessibility education research and curriculum development.

In summary, the first study develops a methodological guide for the development of accessible virtual educational environments from a systemic approach; the second study in an SLR carries out research studies in Saudi Arabia and abroad to study the issue of web accessibility on government and university websites; The third study provides a historical review of the accessibility of online higher education and the fourth study investigates common themes and methods addressed in the computer education literature, focusing on how research is trying to improve ways to integrate accessibility into the computer education curriculum. However, these studies are not as detailed as ours, nor do they present a bibliometric analysis. For example, there is a lack of information about the empirical methods used for web accessibility evaluation, disabilities, versions of the WCAG and their conformance levels, the types of tools used in evaluating educational websites (end-users, automated tools, experts, or a combination of these), errors found in each of the selected jobs, and what disabilities they affect. In addition, our SLR is updated to October 2019. Therefore, these papers do not cover the scope of our research questions on web accessibility of educational websites, nor do they reach the same level of detail and accuracy.

Web accessibility has become more important in recent years, yet websites remain inaccessible to certain sectors of the population. There are the WCAG that allow the fulfillment of the success criteria in the websites and laws that regulate them in different countries. However, little or no experience with accessibility by website developers and a lack of accurate information on the best ways to quickly and easily identify accessibility issues using different accessibility evaluation methods [28] continues to limit access to websites by people with disabilities.

The World Health Organization (WHO) in its 2011 World Disability Report estimates that ''more than a billion people are estimated to live with some form of disability, or about 15 % of the world's population (based on 2010 global population estimates). This is higher than previous World Health Organization estimates, which date from the 1970s and suggested around 10 %'' [29, pp. 7]. According to WHO statistics, the increase in the number of people with disabilities in the world is notorious; therefore, it is estimated that there are millions of children with school-age disabilities. In several countries, basic laws provide for these students to be enrolled in regular schools. However, for universal learning, action is needed, including the development of a material accessible to all students [30]. Hence the importance of an SLR to know the accessibility compliance of educational websites, to analyze their empirical evaluation methods and the most common errors found.

### 2) DEVELOPMENT OF A REVIEW PROTOCOL

The purpose of this paper is to present the last 10 years of research on the accessibility of educational websites. To achieve this goal, an SLR is essential. A selection process is defined and carried out to study much of the most relevant literature in the evaluation of educational websites.

#### *a: RESEARCH QUESTIONS*

Ten research questions were defined in order to accomplish the goal of this SLR [31]. These research questions and their motivation are shown in Table 2.

Given the previous research questions, the PICOC method proposed by Petticrew and Roberts [32] has been followed to define the review scope:

- **Population (P):** Web accessibility.
- **Intervention (I):** Educational websites.
- **Comparison (C):** No comparison intervention in this study, as the aim of this SLR is to analyze the empirical methods of web accessibility evaluation and the errors described.
- **Outcomes (O):** Awareness of the creators of educational websites.
- **Context (C):** Education related environments.

**TABLE 2.** Research questions.

| No. | Research question | Motivation |
|---|---|---|
| RQ1 | Which journals publish papers on web accessibility in education? | To examine the different journals in which the selected papers have been published. |
| RQ2 | What is the ranking of the journals of the selected papers? | To analyze the quality and relevance of the papers found. |
| RQ3 | What is the frequency of publication of web accessibility studies in education over time? | To explore the evolution of the publications over time. |
| RQ4 | What are the standards and disability laws used in the selected papers? | To determine the standards and disability laws used in the selected papers. |
| RQ5 | What empirical methods are used to evaluate the accessibility of educational websites? | To examine the types of empirical validation used to evaluate the accessibility of educational websites. |
| RQ6 | What are the disabilities analyzed in accessibility evaluations of educational websites? | To identify the disabilities analyzed in accessibility evaluations of educational websites. |
| RQ7 | What are the WCAG and conformance levels that have been used in the evaluation of educational websites? | To analyze the WCAG and conformance levels that have been used in the evaluation of educational websites. |
| RQ8 | What type of online tools or services, real users and experts have helped to evaluate web accessibility? | To provide information about automated web accessibility evaluation tools used, real users, and experts who have helped to determine if web content meets accessibility standards. |
| RQ9 | What is the number of errors found on educational websites by priorities and principles? | To provide information on the most common accessibility errors found on educational websites by principle and priority according to the WCAG. |
| RQ10 | What are the results obtained in the evaluation of accessibility of educational websites? | To extract the results obtained from the evaluation of the accessibility of educational websites. |

The results of the SLR answer the research questions posed through the analysis and interpretation of the evidence found.

### b: SEARCH STRATEGY

The search string should provide the maximum coverage but be of a manageable size. The terms used, which are derived from the research questions, have been selected using five different scopes as a starting point: 1) the context site, which examines web portals, websites and web pages; 2) the accessibility, WCAG covers a wide range of recommendations for making web content more accessible; 3) education as the specific field of application; 4) disability, accessibility of websites for people with some type of disability; and 5) the research type that is related to empirical studies. The boolean operator OR is used to join alternative terms and the boolean operator AND is used to join two main parts. In addition, the wildcard (*) is used to enclose both the singular and plural of each term and to search for keywords containing certain characters. Double quotes are used to search for exact phrases. From these major search terms, replacement terms were identified. The search string is shown in Table 3.

**TABLE 3.** Search string.

| Scope | String |
|---|---|
| Site context | (website OR "web site" OR "Internet site" OR site OR "web portal" OR "web page" OR web OR "electronic page" OR "digital page") AND |
| Accessibility | (WCAG OR "web accessibility" OR accessibility OR "universal design" OR "accessibility level" OR "accessibility evaluation" OR "accessibility problems") AND |
| Education | ("education*" OR university OR school OR higher OR "High schools" OR colleges) AND |
| Disabilities | ("disabilit*") AND |
| Research type | (empiric* OR eval* OR assessm* OR test OR experiment OR method OR approach* prediction OR "case study" OR measure OR estimation OR metric OR validation OR framework OR prototype OR survey) |

### c: INCLUSION AND EXCLUSION CRITERIA

The selection process of the papers has a great influence on the results obtained. Each study found from the initial search process was evaluated to decide whether or not it should be admitted as one of the selected studies. If a paper does not meet the full set of inclusion criteria or meets any exclusion criteria, it will be excluded from the review. The inclusion criteria are:

- I1. The paper must be a full or short paper (not an abstract).
- I2. The paper presents empirical results.
- I3. The paper is published in a high-impact journal, ranked in Scimago Journal Rank (SJR) or Journal Citation Reports (JCR).

The papers that conformed to at least one of the following criteria were excluded:

- E1. Papers published before 2009 because WCAG 2.0 was published by the W3C on 11 December 2008.
- E2. Papers published in sources other than journals.
- E3. Papers written in a language other than English.
- E4. Papers containing keywords other than accessibility.
- E5. Papers assess the accessibility in websites other than educational websites.

Bearing in mind that keywords represent the content of a paper, E4 excludes all papers that do not have ''accessibility'' as a keyword or its replacement terms ''web accessibility'' or ''WCAG''.

### d: QUALITY ASSESSMENT

The purpose of this quality assessment (QA) is to weight the importance of each of the papers selected when the results are discussed and to guide the interpretation of findings [20].

Each QA obtains a score of one for the fulfillment of each clause 1) web accessibility is detailed in the paper; 2) web

**TABLE 4.** Quality assessment checklist.

| No. | Quality assessment question | Answer |
|---|---|---|
| QA1 | Is web accessibility detailed in the paper? | (+1) Yes / (+0) No |
| QA2 | Is the web accessibility evaluation method specified in the paper? | (+1) Yes / (+0) No |
| QA3 | Are the empirical results of the web accessibility evaluation shown? | (+1) Yes / (+0) No |
| QA4 | Does the paper discuss any findings of web accessibility evaluation? | (+1) Yes / (+0) No |
| QA5 | Are common web accessibility errors described in the results? | (+1) Yes / (+0) No |
| QA6 | Is the journal where the paper was published indexed in SJR? | (+1) if it is ranked Q1, (+0.75) if it is ranked Q2, (+0.5) if it is ranked Q3, (+0.25) if it is ranked Q4. |
| QA7 | Is the journal where the paper was published indexed in JCR? | (+1) if it is ranked Q1, (+0.75) if it is ranked Q2, (+0.5) if it is ranked Q3, (+0.25) if it is ranked Q4. |

accessibility evaluation methods are used; 3) web accessibility empirical results are determined; 4) paper discusses web accessibility assessment results; 5) there are web accessibility errors in the results; 6) the journal is indexed in SJR, for the evaluation of the quartiles of the papers in SJR we use the SJR website;[1] 7) the journal is indexed in JCR, for the evaluation of the quartiles of the JCR papers we use Clarivate's JCR.[2] Table 4 shows the summary of the quality assessment as a checklist.

### *B. CONDUCTING THE SYSTEMATIC LITERATURE REVIEW STUDY*

#### 1) IDENTIFICATION OF RESEARCH

An SLR involves searching the literature for topics that have been covered and where they have been published. Th search process involves the selection of the search resources and the identification of the search terms. In a research in 2019, on the evaluation of the recovery qualities of Google Scholar, PubMed and 26 academic search systems, in their findings demonstrated that Google Scholar is inappropriate as a primary resource [33]. Therefore, in this research we selected the most relevant academic sources in software engineering and education to search the papers: ACM Digital Library, IEEE Xplore Digital Library, Scopus, Springer Link, and Web of Science. These databases were chosen according to the following criteria:

- It gathers the references of the main scientific publications essential for the support of research.
- Papers published in the databases are peer-reviewed.

[1] https://www.scimagojr.com/

[2] https://clarivate.com/webofsciencegroup/solutions/journal-citation-reports/

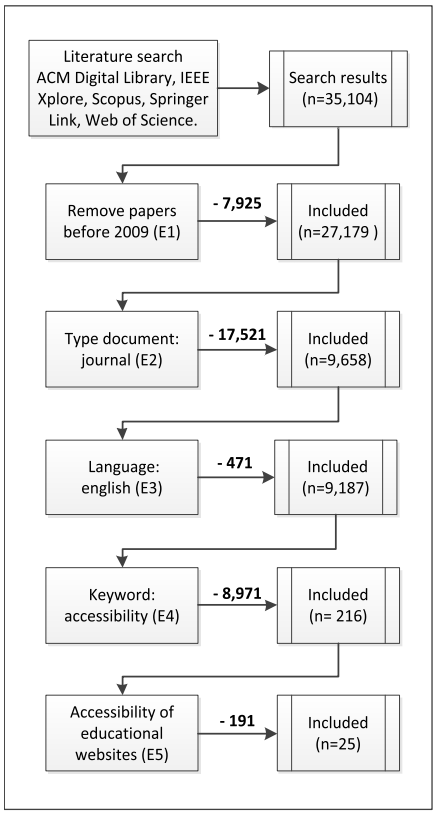


**FIGURE 2.** Diagram of exclusion and inclusion of papers.

- It indexes high quality papers.
- It allows the use of search strings with Boolean operators to logically connect keywords.

#### 2) SELECTION OF STUDIES

The search process took place in October 2019. A total of 35,104 papers were found with the search string shown in Table 3. Of the 35,104 papers, 7,925 were excluded after applying E1 because they had been published before 2009, 17,521 papers were excluded after applying E2 because they were not published in journals, 471 papers were excluded after applying E3 because they were not written in English. The remaining 9,187 papers were evaluated the existence of the keyword ''accessibility'', 8,971 were excluded after applying E4 because they do not have keyword ''accessibility''. The full texts of the remaining 216 documents were screened, 191 documents were excluded and 25 were finally selected after applying E5. A large number of papers were excluded because they analyze websites that are not educational, e.g. tourism websites, municipal websites, government health websites, health information websites, e-commerce websites, finance websites, banking websites, corporate websites, cultural events websites, websites of international association organizations in the area of science and engineering, social networking websites, and so on that are not the focus of this SLR. Figure 2 shows the diagram of inclusion and exclusion of papers.

#### 3) STUDY QUALITY ASSESSMENT

Table 5 presents a list of the selected papers, together with their quality control results. In addition, a normalization column has been created in order to use a common scale from 0 to 1. For this purpose [34], the minimum-maximum normalization was used, which preserves the relationship between the original data values. The values in this column are transformed using the following formula (1):

$$Normalization = \frac{Score - min(Score)}{[max(Score) - min(Score)]} \quad (1)$$

where the min(Score) is equal to 0, the max(Score) is equal to 7 and the Score is the value to be calculated.

### C. REPORTING THE SYSTEMATIC LITERATURE REVIEW STUDY

The aim of this section is to answer the research questions posed in the review protocol. To do this, the results are divided into two parts. In the first part, a bibliometric analysis is performed to answer the research questions RQ1, RQ2 and RQ3; in the second part, the systematic review literature is presented with the most relevant data to answer the research questions RQ4, RQ5, RQ6, RQ7, RQ8, RQ9 and RQ10.

## IV. RESULTS

This section describes the results obtained from each research question defined in the Table 2. The first Section IV-A, Bibliometric Analysis, comprises relevant data such as type of journal, number of papers per JCR and SJR journal and number of papers per year. The second Section IV-B, the SLR, presents a mapping of the selected studies.

### A. BIBLIOMETRIC ANALYSIS

#### 1) RQ1. WHICH JOURNALS PUBLISH PAPERS ON WEB ACCESSIBILITY IN EDUCATION?

The papers including this research are published in 17 journals. As shown in Figure 3, the journals with the greatest number of publications are the UAIS with 7 papers and the IEEE Access and the JICT with 2 papers respectively. The remaining 14 journals have only one selected paper each one (see full information in Table 7, Appendix A).

The countries of the journals where the papers are published through the SJR website were also collected. The countries of the 17 journals where the selected papers were published are Germany with 9 papers, the United States with 5 papers, the United Kingdom with 4 papers and Malaysia with 2 papers. The countries of Austria, Canada, Italy, the Netherlands and Saudi Arabia each have one publication.

#### 2) RQ2. WHAT IS THE RANKING OF THE JOURNALS OF THE SELECTED PAPERS?

The reputation of papers can be measured by the ranking of the journals where they are published. Of the 25 selected papers, 13 papers are published in journals ranked in SJR, 10 papers in SJR and JCR and 2 papers in neither ranking. Figure 4 shows that the highest concentration of publications

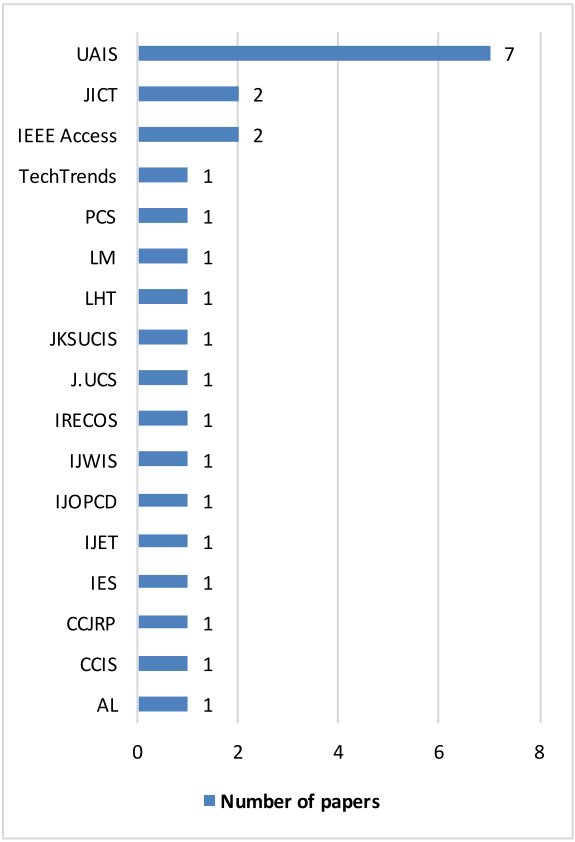


**FIGURE 3.** Number of papers per journal.

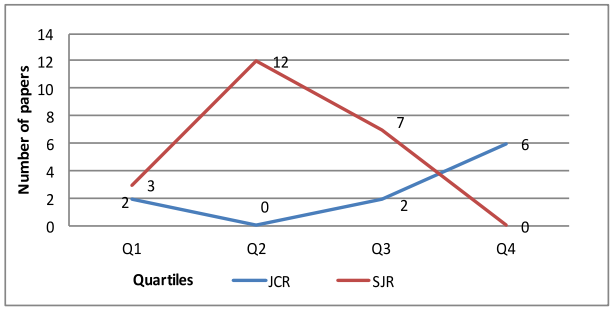


**FIGURE 4.** Number of papers per journal indexed in JCR and SJR.

is in SJR Q2 and JCR Q4. Of the 25 papers, 3 are ranked in Q1 in SJR and 2 in Q1 in JCR as the best publications. The quartiles of the JCR and SJR journals were consulted according to the year of publication of the papers. The quartiles of the 2019 SJR and JCR journals have not yet been published at the moment of writing this paper. Therefore, the 2018 quartiles were taken in this SLR for papers [55]–[59] published in 2019 (see full information in Table 7, Appendix A).

#### 3) RQ3. WHAT IS THE FREQUENCY OF PUBLICATION OF WEB ACCESSIBILITY STUDIES IN EDUCATION OVER TIME?

The selected papers were published between 2009 and 2019. Figure 5 displays the number of papers published by year. As can be seen, the greatest number of publications were in

**TABLE 5.** Selected papers and quality assessment results.

| Paper | Pub. Year | Pub. Name | Quality assessment | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | QA1 | QA2 | QA3 | QA4 | QA5 | QA6 | QA7 | Score | Normalization |
| [35] | 2010 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0 | 5.75 | 0.82 |
| [36] | 2013 | Journal of Universal Computer Science (J.UCS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [37] | 2013 | Library Hi Tech (LHT) | 1 | 1 | 1 | 1 | 1 | 1 | 0.5 | 6.5 | 0.92 |
| [38] | 2014 | International Education Studies (IES) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [39] | 2014 | International Review on Computers and Software (IRECOS) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [40] | 2014 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [41] | 2014 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [42] | 2014 | Library Management (LM) | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 6 | 0.85 |
| [43] | 2015 | International Journal of Emerging Technologies in Learning (IJET) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [44] | 2015 | Communications in Computer and Information Science (CCIS) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [45] | 2015 | Advances in Librarianship (AL) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [46] | 2016 | Journal of Information and Communication Technology-Malaysia (JICT) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [47] | 2017 | International Journal of Online Pedagogy and Course Design (IJOPCD) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 5 | 0.71 |
| [48] | 2017 | Journal of Information and Communication Technology (JICT) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0 | 5.75 | 0.82 |
| [49] | 2017 | International Journal of Web Information Systems (IJWIS) | 1 | 1 | 1 | 1 | 1 | 0.5 | 0 | 5.5 | 0.78 |
| [50] | 2017 | Procedia Computer Science (PCS) | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 5 | 0.71 |
| [51] | 2017 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [52] | 2018 | IEEE Access | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1 |
| [53] | 2018 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [54] | 2018 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [55] | 2019 | Universal Access in the Information Society (UAIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0.25 | 6 | 0.85 |
| [56] | 2019 | Journal of King Saud University - Computer and Information Sciences (JKSUCIS) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0 | 5.75 | 0.82 |
| [57] | 2019 | Community College Journal of Research and Practice (CCJRP) | 1 | 1 | 1 | 1 | 1 | 0.75 | 0 | 5.75 | 0.82 |
| [58] | 2019 | TechTrends | 1 | 1 | 1 | 1 | 1 | 0.75 | 0 | 5.75 | 0.82 |
| [59] | 2019 | IEEE Access | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 7 | 1 |

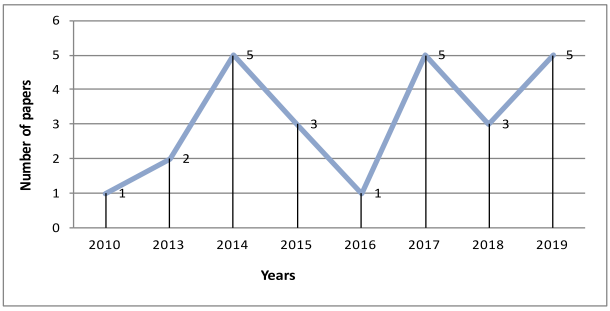


**FIGURE 5.** Number of papers per year.

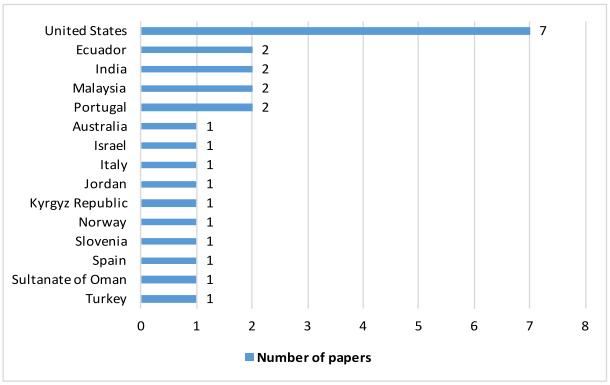


**FIGURE 6.** Number of papers per country.

the years 2014, 2017 and 2019 with five papers each year, in the years 2015 and 2018 three papers, in the year 2013 two papers and in the years 2010 and 2016 one paper each year (see full information in Table 7, Appendix A).

The following countries were taken from the papers according to where the educational websites were studied. It should be noted that the papers [52], [59] published by Ecuador refer to Universities websites in Latin America. Figure 6 shows that the leading countries in the topic of interest are United States with 7 papers, Ecuador, India, Malaysia and Portugal with 2 papers each one. The countries of Australia, Israel, Italy, Jordan, Kyrgyz Republic, Norway, Slovenia, Spain, Sultanate of Oman and Turkey have one publication each one.

### B. SYSTEMATIC LITERATURE REVIEW

#### 1) RQ4. WHAT ARE THE STANDARDS AND DISABILITY LAWS USED IN THE SELECTED PAPERS?

Figure 7 shows the number of papers per web accessibility standard. All 25 papers use the WCAG to evaluate the accessibility of educational websites, regardless of their versions. In addition, 7 papers use Section 508, 1 paper uses ISO/IEC 24751 and 1 paper uses SI 5568.

Of the 25 papers selected, 14 papers detail disability laws that promote improved quality of life for people with disabilities. The disability laws used in the papers are listed below (see full information in Table 8, Appendix A):

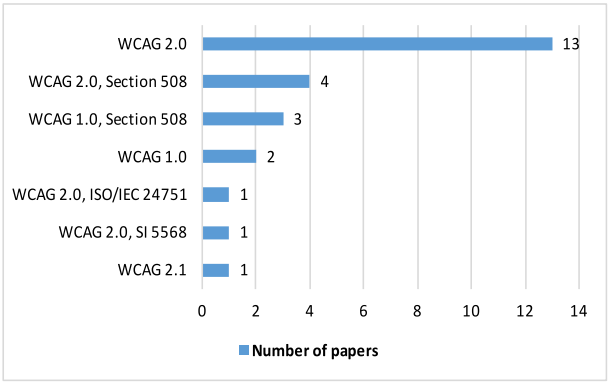


**FIGURE 7.** Number of papers per web accessibility standard.

- Paper [35] Americans with Disabilities Act (ADA), Section 504 of the Rehabilitation Act of 1973, US Public Law 105-220.
- Paper [36] Constitution of the Portuguese Republic.
- Paper [38] Law n. 51/2003 (2003), Law n. 56/2007 (2007).
- Paper [41] Americans with Disabilities Act (ADA), Section 504 of the Rehabilitation Act of 1973, Americans with Disabilities Amendments Act of 2008.
- Paper [42] Convention on the Rights of Persons with Disabilities (CRPD), Australian Human Rights Commission (AHRC), Disability Services Act 1986 (Cth).
- Paper [43] Equality Act 2010 (EQA).
- Paper [46] Law of Malaysia (2008) on Person with Disabilities Act 2008 (Act 685).
- Paper [47] Americans with Disabilities Act (ADA), Individuals with Disabilities Education Act (IDEA), Section 504 of the Rehabilitation Act of 1973.
- Paper [48], [50] Convention on the Rights of Persons with Disabilities (CRPD).
- Paper [53] Convention on the Rights of Persons with Disabilities (CRPD), Equal Rights for People with Disabilities (Service Accessibility Adjustments), Equal Rights for People with Disabilities Law.
- Paper [54] Norwegian law of Disability and Discrimination Act, Regulation for universal design of information and communication technology (ICT) solutions, Norwegian Discrimination and Accessibility Act, Act relating to Universities and University Colleges (UHL).
- Paper [57], [58] Americans with Disabilities Act (ADA).

#### 2) RQ5. WHAT EMPIRICAL METHODS ARE USED TO EVALUATE THE ACCESSIBILITY OF EDUCATIONAL WEBSITES?

The three methods that have been used in the papers for the evaluation of accessibility of educational websites are: 1) automatic methods using programs or online services 80 % of the selected papers; 2) manual methods with expert and real user validation 12 %; 3) the combination of both 8 %. Figure 8 shows the papers grouped by the three evaluation methods (see full information in Table 9, Appendix A).

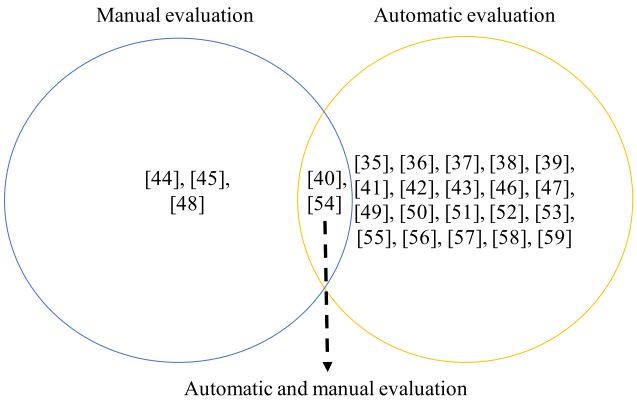


**FIGURE 8.** Papers per evaluation method.

### 3) RQ6. WHAT ARE THE DISABILITIES ANALYZED IN ACCESSIBILITY EVALUATIONS OF EDUCATIONAL WEBSITES?

All the papers talk about disabilities, however, only papers [38]–[40], [42], [43], [45], [48], [49], [53], [54] specify in their research the disabilities with which they work, which are blind users or those with low vision, color blindness, users with cognitive or language limitations, or users who are deaf and communicate using sign language, dyslexia, mobility impairments, learning disabilities, speech disabilities, photosensitivity and combinations of these. The other selected papers analyze the educational websites based on the disabilities described in the WCAG (see full information in Table 9, Appendix A).

### 4) RQ7. WHAT ARE THE WCAG AND CONFORMANCE LEVELS THAT HAVE BEEN USED IN THE EVALUATION OF EDUCATIONAL WEBSITES?

Figure 9 shows the number of papers per WCAG. The conformance levels used in each paper are described below (see full information in Table 10, Appendix A):

- Of the 25 papers, 5 were evaluated with WCAG 1.0. Papers [35], [37], [41] do not specify the level of conformance. Papers [49], [51] were evaluated with a level of conformance AA.
- Of the 25 papers, 19 were evaluated with WCAG 2.0. Papers [38]–[40], [43], [44], [46], [52] were evaluated with conformance level A; papers [45], [47], [48], [50], [53]–[55] with conformance level AA; papers [57], [58] with conformance levels A and AA; papers [36], [42], [56] with conformance levels A, AA and AA.
- Paper [59] was the only one evaluated with WCAG 2.1 and conformance levels A and AA.

### 5) RQ8. WHAT TYPE OF ONLINE TOOLS OR SERVICES, REAL USERS AND EXPERTS HAVE HELPED EVALUATE WEB ACCESSIBILITY?

Figure 10 shows that 20 of the 25 papers were not evaluated with real users and experts. Two of the remaining 5 were evaluated with real users and the other 3 with automatic tools, real users and experts. The web accessibility evaluation in

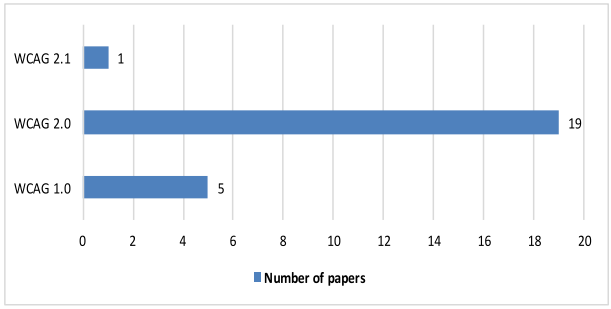


**FIGURE 9.** Number of papers per version of the WCAG.

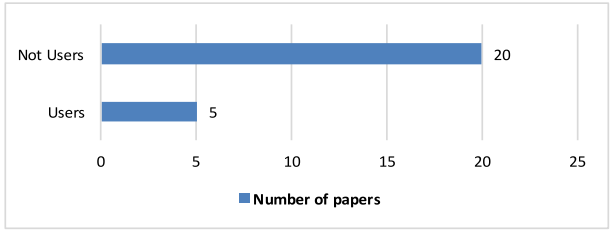


**FIGURE 10.** Number of papers evaluated with users.

the paper [40] was carried out with 33 students. The web accessibility evaluation in the paper [54] was carried out with JAWS, 2-switch and an anonymous user group. Paper [44] carried out the evaluation with 3 automatic tools, 12 students and 2 experts in usability. Paper [45] did the evaluation with 3 automatic tools and one JAWS expert. Paper [48] made the evaluation with 1 automatic tool and 16 blind users (see full information in Table 11, Appendix A). The automatic web accessibility evaluation tools that were used in the 23 selected papers are AChecker, Accessibility wizard, Accessibility valet, Accessibility colour wheel, aXe, Bobby, Colour contrast analyser, CynthiaSays, Etre accessibility check, EvalAccess, EIII page checker, Functional accessibility evaluator, Fujitsu web accessibility inspector, FAE, HiSoftware compliance sheriff, Magenta, Ocawa, Siteimprove, TAW, TENON, Total validator, WAVE, WebAcc checker, Webpage analyzer, W3C markup validation service, W3C CSS validation service (see full information in Table 9, Appendix A).

Figure 11 shows the number of real users, experts and the number of automatic tools that are repeated more than once in the selected papers to evaluate the accessibility of websites (see full information in Table 9, Appendix A).

Web accessibility assessment tools are software programs or online services that help determine if web content meets WCAG [60]. A tool of this type can never replace the revision made by an expert in web accessibility, so it should be used as a first step, but not the only one. Automatic web accessibility evaluation tools or online services can sometimes generate erroneous or incorrect results, requiring validation by users and experts [61]. The four most commonly used automatic web accessibility evaluation tools are described below.

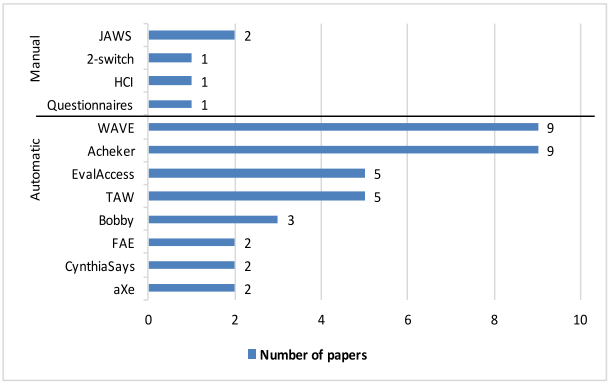


**FIGURE 11.** Number of manual and automatic tools.

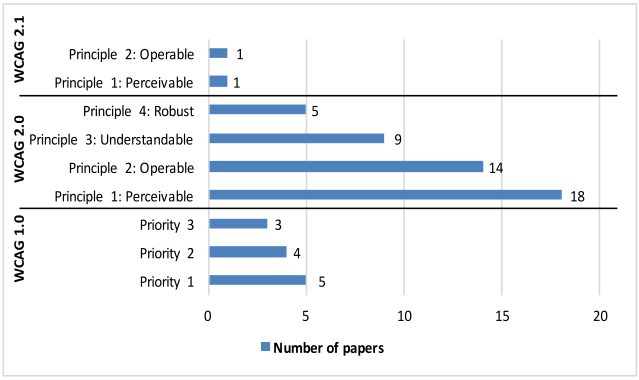


**FIGURE 12.** Number of papers per priorities and principles.

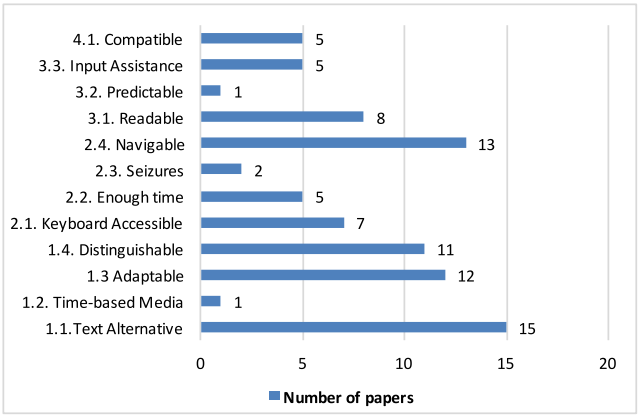


**FIGURE 13.** Number of papers per guidelines WCAG 2.0.

1) WAVE:[3] is a suite of evaluation tools that help authors make their web content more accessible to individuals with disabilities. WAVE can identify many accessibility and WCAG errors, but also facilitates human evaluation of web content.
2) AChecker:[4] checks single HTML pages for conformance with accessibility standards to ensure the content can be accessed by everyone.
3) EvalAccess: takes the URL of the website as input and the output is displayed in a table with the following information: 1) checkpoint or success criteria where the violation has occurred; 2) description of the checkpoint, name of the HTML attribute containing the error/warning; 3) URL of the mobile web best practices guideline on the W3C site where the violated guideline is explained; 4) list of line numbers in the source code where the error/warning has been generated [62].
4) TAW:[5] is an automatic on-line tool for analyzing website accessibility. The aim of TAW is to check the level of accessibility achieved in the design and development of web pages in order to access to all persons irrespective of their characteristics. It is intended for users without experience that want to know the degree of accessibility of their websites as well as for field professionals like webmasters, developers, web designers and so on.

According to WebAIM [63], in their article on using JAWS to evaluate web accessibility, they state that it is important to evaluate the accessibility of web content with a screen reader. Although screen readers are complicated, it is possible to test the accessibility of web content without being an expert user.

### 6) RQ9. WHAT IS THE NUMBER OF ERRORS FOUND ON EDUCATIONAL WEBSITES BY PRIORITIES AND PRINCIPLES?

Figure 12 presents the number of selected papers with errors for each priority of WCAG 1.0 and for each principle of WCAG 2.0 and WCAG 2.1. The largest number of papers with errors found is in the perceivable principle (see full information in Table 11, Appendix A).

According to the levels of conformance of the WCAG 1.0 to comply with 1) Conformance Level "A" all Priority 1 checkpoints are satisfied; 2) Conformance Level "Double-A" all Priority 1 and 2 checkpoints are satisfied; 3) Conformance Level "Triple-A" all Priority 1, 2, and 3 checkpoints are satisfied. As shown in Figure 12, there are errors in all priorities of WCAG 1.0. This evidences that the websites analyzed in the papers do not comply with the conformance levels A, AA and AAA (see full information in Table 12, Appendix B).

The WCAG 2.0 success criteria are the key to determining the levels of conformance, not the techniques [4]. Figure 13 presents the number of selected papers with errors in the WCAG 2.0 guidelines. The percentage of errors found by level of conformance is 66 % with level A, 22 % with level AA and 12 % with level AAA (see full information in Table 13, Appendix B).

Figure 14 shows the number of selected papers with errors in the WCAG 2.1 guidelines. The percentage of errors found by level of conformance is 80 % with level A, 20 % with level AA and 0 % with level AAA (see full information in Table 13, Appendix B).

[3] https://wave.webaim.org/
[4] https://achecker.ca/checker/index.php
[5] https://www.tawdis.net/

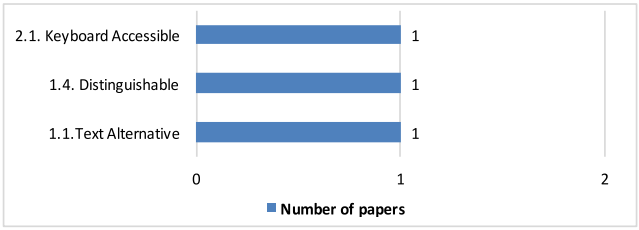


**FIGURE 14.** Number of papers per guidelines WCAG 2.1.

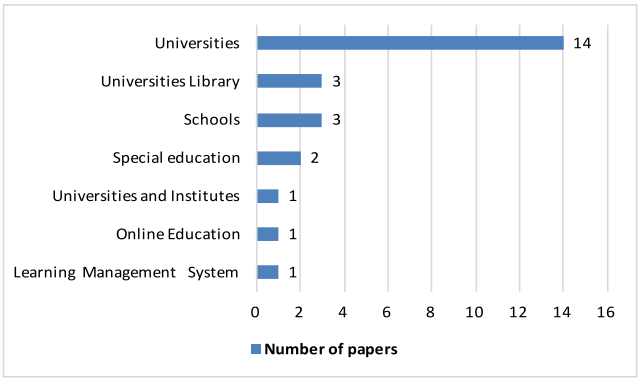


**FIGURE 15.** Sources of educational websites.

**TABLE 6.** Number of websites analyzed.

| Description | Websites |
|---|---|
| Universities library | 10,087 |
| Schools | 1,690 |
| Universities | 922 |
| Special education | 75 |
| Universities and Institutes | 59 |
| Universities and College | 44 |
| Online Education | 21 |
| Learning Management System | 5 |
| **Total** | **12,903** |

#### 7) RQ10. WHAT ARE THE RESULTS OBTAINED IN THE EVALUATION OF ACCESSIBILITY OF EDUCATIONAL WEBSITES?

Figure 15 presents the sources of the educational websites analyzed in the 25 selected papers. We can see that most papers evaluate the accessibility of university websites (see full information in Table 9, Appendix A).

Table 6 shows the number of websites analyzed. It can be seen that the largest number of websites analyzed are in the libraries of the universities, the school and the universities.

The benefits of WCAG 2.0 are: 1) a cooperatively developed international standard; 2) applicable to the most advanced technologies; 3) clearer criteria; 4) flexible, adaptable; 5) examples of practical application and information [64]. Using the WCAG 2.1 success criteria, user groups were determined that would be helped by correcting the errors found in WCAG 2.0 and 2.1 guidelines.

## V. DISCUSSION

Considering the publication of the WCAG 2.0 on December 11, 2008, we selected the papers published since 2009. However, five of the 25 selected papers perform the evaluation with the WCAG 1.0.

The SLR begins by making a bibliometric analysis of the most relevant information obtained from the selected papers. The selected papers were the product of publications in 17 journals. As a result of the ranking of publication sources, 13 papers were published in journals ranking SJR and 10 in SJR and JCR. In SJR we have 3 papers in Q1, 12 papers in Q2 and 7 papers in Q3. In JCR we have 2 papers in Q1, 2 papers in Q3 and 6 papers in Q4.

Springer's journals are the source that contains the largest number of relevant studies. The countries with the greatest contribution to the topic of web accessibility are United States, Ecuador, India, Malaysia and Portugal. The United States promotes accessibility compliance on websites through Section 508. From this analysis, it has been possible to see the interest and growth of this research topic.

On the W3C's "Accessibility Evaluation Tools List" [60] web page, the filters section classifies the tools according to the following accessibility standards and guidelines:

- WCAG 1.0 - W3C Web Content Accessibility Guidelines 1.0.
- WCAG 2.0 - W3C Web Content Accessibility Guidelines 2.0.
- BITV, German government standard.
- RGAA, French government standard.
- JIS, Japanese industry standard.
- WCAG 2.1 - W3C Web Content Accessibility Guidelines 2.1.
- Irish National IT Accessibility Guidelines.
- MAAG 1.0 - Korea government standard.
- Section 508, US federal procurement standard.
- SI 5568, Israeli web accessibility guidelines.
- Stanca Act, Italian accessibility legislation.

Standards establish frameworks that help design accessible websites and evaluate the accessibility of existing websites. Of which it can be seen in the selected papers that the WCAG 1.0, WCAG 2.0, WCAG 2.1, Section 508, US federal procurement standard and SI 5568, Israeli web accessibility guidelines are used. Many countries have had laws in place for years requiring government and certain corporate websites to be accessible.

The need for the Web to be universal and accessible to everyone has been present since the beginning of the Web, as it was a requirement perceived in its design by its creator Tim Berners-Lee. However, bad practices in the design and development of websites have resulted in accessibility barriers. The increase in the number of people with disabilities in the world, the right to education and their access into regular education in some countries is a determining factor in the compliance of educational websites with the WCAG.

The SLR describes the empirical methods used to assess the accessibility of educational websites, the WCAG and conformance levels used, the tools or online services with which they have been assessed, the actual users and experts who have helped to assess, the disabilities analyzed, the errors found and the results obtained. The detailed analysis of the SLR is presented below.

The empirical methods used for the evaluation of web accessibility were with real users and expert validation, automatic methods using programs or online services, and the combination of both. Five papers were evaluated with WCAG 1.0, 19 with WCAG 2.0 and 1 with WCAG 2.1. Three papers out of 25 do not specify in their results the level of conformance. In the results of two papers the authors analyze educational websites with real users, including users with disabilities and three papers with real users and experts validation. In the results of 23 papers the authors used automatic tools to evaluate the accessibility of educational websites, the most used automatic tools are Achecker, Evalaccess, TAW and WAVE.

S. Abou-Zahra works with the W3C Web Accessibility Initiative (WAI) as the Accessibility Strategy and Technology Specialist; on the diverse abilities and barriers in the use of the Web by people with disabilities stipulates that ''visual disabilities range from mild or moderate vision loss in one or both eyes (''low vision'') to substantial and uncorrectable vision loss in both eyes (''blindness''). Some people have reduced or lack of sensitivity to certain colors (''color blindness''), or increased sensitivity to bright colors. These variations in perception of colors and brightness can be independent of the visual acuity'' [65]. All the papers analyzed talk about disabilities, however, only 10 papers specify in their research the disabilities they work with. The disabilities that predominate in these papers are blindness, low vision and color blindness. The errors found in the WCAG 2.0 and WCAG 2.1 success criteria presented in the Table 13 were mapped with the benefits of understanding WCAG 2.1 [66] (see full information in Table 14, Appendix B) managing to determine that correcting these errors would benefit the following groups of people with disabilities:

- Blind, low vision, color-blindness, color vision deficiency, see no color, visual tracking problems.
- Deaf.
- Deaf-blind.
- Cognitive disabilities, intellectual disabilities, attention deficit disorders, short-term memory.
- Language disabilities, learning disabilities, reading disabilities, writing disabilities.
- Physical disabilities, hand tremors, mobility impairments, motor impairments.
- Photosensitive epilepsy, photosensitive seizure disorders.

The automatic tools used in the web accessibility evaluation of at least 5 papers are AChecker, EvalAcces, TAW and WAVE. According to the list of web accessibility evaluation tools published by W3C that are already updated with WCAG 2.1 are Color Contrast Accessibility, TAW and WAVE [60], for this reason, 19 papers have been evaluated with WCAG 2.0.

In WCAG 1.0 the most common errors are in priority 2 which is equivalent to 50 % of the total errors. A web content developer should satisfy this checkpoint. Otherwise, one or more groups will find it difficult to access information in the document. Satisfying this checkpoint will remove significant barriers to accessing web documents. In WCAG 2.0 the greatest number of errors are presented in principle 1 Perceivable which is equivalent to 40 % of the total errors, 35 % Operable, 19 % Understandable and Robust 6 %. In the WCAG 2.1, 60 % of errors are in principle Perceivable and 40 % in the Robust principle. This means that information and user interface components are not presented to users in ways they can perceive. A website is perceivable when it allows a user to navigate with one or more of their senses.

In summary, the educational websites analyzed in the 25 papers do not comply with WCAG and their A, AA and AAA conformance levels. Educational websites should make significant efforts to improve their accessibility and create more inclusive websites. Empirical evaluation methods used for web accessibility could be improved by adopting automatic tools for website construction and manual mechanisms with experts for testing.

## VI. LIMITATIONS OF THE STUDY

An SLR can be influenced by a number of limitations. One of these is author bias in data extraction. To avoid author bias, inclusion and exclusion criteria were used in the selection of papers. In addition, to include as many representative terms on web accessibility, websites, education, disability, and empirical methods as possible, we identified synonyms and related terms, and evaluated the results of preliminary search strings to analyze whether the data retrieved were relevant to the scope of this literature review. Through this iterative process, the query string was refined to ensure useful and accurate data extraction. All three authors participated in planning the SLR study to identify its need and develop a review protocol. The first author conducted the data extraction, while the other two reviewed the final results.

Another limitation is the process of searching through a query string that may have excluded some relevant papers. Although a systematic and well-defined protocol is followed, there is no guarantee that all relevant papers from this study will be retrieved. The exclusion of Google Scholar from this review is justified by the need to consider only databases that index content of proven quality [67].

Another important limitation of the study is that some empirical results only define errors by each principle and not by the guidelines. However, the web accessibility problems found have been assigned to a guideline according to their

**TABLE 7.** Data extracted for RQ1, RQ2 and RQ3.

| Paper | RQ1 | | | RQ2 | | RQ3 | |
|---|---|---|---|---|---|---|---|
| | Pub. Type | Pub. Name | Subject Area | JCR | SJR | Pub. Year | Pub. Dates |
| [35] | J | Universal Access in the Information Society | Computer Science | ..... | Q2 | 2010 | March |
| [36] | J | Journal of Universal Computer Science | Computer Science | Q4 | Q2 | 2013 | January |
| [37] | J | Library Hi Tech | Computer Science | Q3 | Q1 | 2013 | March |
| [38] | J | International Education Studies | Social Sciences | ..... | Q3 | 2014 | May |
| [39] | J | International Review on Computers and Software | Computer Science | ..... | Q3 | 2014 | May |
| [40] | J | Universal Access in the Information Society | Computer Science | Q4 | Q2 | 2014 | June |
| [41] | J | Universal Access in the Information Society | Computer Science | Q4 | Q2 | 2014 | June |
| [42] | J | Library Management | Social Sciences | ..... | Q1 | 2014 | March |
| [43] | J | International Journal of Emerging Technologies in Learning | Engineering | ..... | Q3 | 2015 | August |
| [44] | J | Communications in Computer and Information Science | Computer Science | ..... | Q3 | 2015 | August |
| [45] | J | Advances in Librarianship | Social Sciences | ..... | Q3 | 2015 | December |
| [46] | J | Journal of Information and Communication Technology-Malaysia | Computer Science | ..... | Q3 | 2016 | December |
| [47] | J | International Journal of Online Pedagogy and Course Design | Social Sciences | ..... | ..... | 2017 | January |
| [48] | J | Journal of Information and Communication Technology | Computer Science | ..... | Q2 | 2017 | June |
| [49] | J | International Journal of Web Information Systems | Computer Science | ..... | Q3 | 2017 | June |
| [50] | J | Procedia Computer Science | Computer Science | ..... | ..... | 2017 | August |
| [51] | J | Universal Access in the Information Society | Computer Science | Q3 | Q2 | 2017 | November |
| [52] | J | IEEE Access | Computer Science | Q1 | Q1 | 2018 | June |
| [53] | J | Universal Access in the Information Society | Computer Science | Q4 | Q2 | 2018 | August |
| [54] | J | Universal Access in the Information Society | Computer Science | Q4 | Q2 | 2018 | November |
| [55] | J | Universal Access in the Information Society | Computer Science | Q4 | Q2 | 2019 | April |
| [56] | J | Journal of King Saud University - Computer and Information Sciences | Computer Science | ..... | Q2 | 2019 | April |
| [57] | J | Community College Journal of Research and Practice | Social Sciences | ..... | Q2 | 2019 | April |
| [58] | J | TechTrends | Computer Science | ..... | Q2 | 2019 | August |
| [59] | J | IEEE Access | Computer Science | Q1 | Q1 | 2019 | September |

Information not provided is marked as "....."

description. Also in 1 paper the errors are not specified, in 3 papers the level of conformity with which they were evaluated is not specified and in 15 papers the disability is not described.

Another limitation is that our SLR does not take into account the grey literature (e.g., blog posts, videos and white papers) in addition to the published (formal) literature (e.g., journal and conference papers). An alternative could be to apply a Multivocal Literature Review (MLR), which is a form of an SLR which includes the grey literature. MLRs are useful for both researchers and practitioners since they provide summaries both the state of the art and practice in a given area. MLRs are popular in other fields and have recently started to appear in software engineering [68].

## VII. CONCLUSIONS AND FUTURE WORK

An SLR has been carried out to analyze papers addressing the accessibility of educational websites. This SLR addresses relevant issues regarding web accessibility evaluation methods, disabilities, WCAG, online web accessibility evaluation tools, accessibility errors, and empirical results.

This SLR was essential in determining the empirical studies on the accessibility of educational websites from 2009 to October 2019. With the SLR, all ten research questions were answered, with the first three being the bibliometric analysis and the other seven the SLR itself, providing a comprehensive analysis of the current state of this research. After searching using the search string in five different electronic databases, 35,104 documents were retrieved. After applying the criteria

**TABLE 8.** Data extracted for RQ4.

| Paper | RQ4 | | |
|---|---|---|---|
| | **Standards** | **Disability laws** | **Country** |
| [35] | WCAG 1.0, Section 508 | Americans with Disabilities Act (ADA), Section 504 of the Rehabilitation Act of 1973, US Public Law 105-220 | United States |
| [36] | WCAG 2.0 | Constitution of the Portuguese Republic | Portugal |
| [37] | WCAG 1.0, Section 508 | ..... | United States |
| [38] | WCAG 2.0 | Law n. 51/2003 (2003), Law n. 56/2007 (2007) | Spain |
| [39] | WCAG 2.0 | ..... | India |
| [40] | WCAG 2.0 | ..... | Italy |
| [41] | WCAG 1.0, Section 508 | Americans with Disabilities Act (ADA), Section 504 of the Rehabilitation Act of 1973, Americans with Disabilities Amendments Act of 2008 | United States |
| [42] | WCAG 2.0 | United Nations Convention on the Rights of Persons with Disabilities in Article 24, Australian Human Rights Commission (AHRC), Disability Services Act 1986 (Cth) | Australia |
| [43] | WCAG 2.0 | Equality Act 2010 (EQA) | Jordan |
| [44] | WCAG 2.0, ISO/IEC 24751, ISO/IEC 40500:2012 | ..... | Slovenia |
| [45] | WCAG 2.0 | ..... | United States |
| [46] | WCAG 2.0, Section 508 | Law of Malaysia (2008) on Person with Disabilities Act 2008 (Act 685) | Malaysia |
| [47] | WCAG 2.0, Section 508 | Americans with Disabilities Act (ADA), Individuals with Disabilities Education Act (IDEA), Section 504 of the Rehabilitation Act of 1973 | United States |
| [48] | WCAG 2.0 | Convention on the Rights of Persons with Disabilities (CRPD) | Malaysia |
| [49] | WCAG 1.0 | ..... | Sultanate of Oman |
| [50] | WCAG 2.0 | Convention on the Rights of Persons with Disabilities (CRPD) | Turkey |
| [51] | WCAG 1.0 | ..... | Kyrgyz Republic |
| [52] | WCAG 2.0 | ..... | Ecuador |
| [53] | WCAG 2.0, SI 5568 | Convention on the Rights of Persons with Disabilities (CRPD), Equal Rights for People with Disabilities (Service Accessibility Adjustments), Equal Rights for People with Disabilities Law | Israel |
| [54] | WCAG 2.0 | Norwegian law of Disability and Discrimination Act, Regulation for universal design of information and communication technology (ICT) solutions, Norwegian Discrimination and Accessibility Act, Act relating to Universities and University Colleges (UHL) | Norway |
| [55] | WCAG 2.0 | ..... | India |
| [56] | WCAG 2.0 | ..... | India |
| [57] | WCAG 2.0, Section 508 | Americans with Disabilities Act (ADA) | United States |
| [58] | WCAG 2.0, Section 508 | Americans with Disabilities Act (ADA) | United States |
| [59] | WCAG 2.1 | ..... | Ecuador |

Information not provided is marked as "....."

**TABLE 9.** Data extracted for RQ5, RQ6 and RQ10.

| Paper | RQ5 | | RQ6 | RQ10 | |
|---|---|---|---|---|---|
| | Evaluated method | Evaluated tools | Disabilities | # Evaluated | Description |
| [35] | Automatic Evaluation Tools | Bobby | ..... | 1,257 | Texas public school institutions |
| [36] | Automatic Evaluation Tools | TAW3 | ..... | 433 | Websites of the Portuguese Secondary Schools |
| [37] | Automatic Evaluation Tools | Bobby | ..... | 56 | North American academic library websites |
| [38] | Automatic Evaluation Tools | TAW | Blind users or those with low vision, users with cognitive or language limitations, or users who are deaf and communicate using sign language | 21 | Spanish Official Online Education web portals |
| [39] | Automatic Evaluation Tools | ACheker, Accessibility valet, CynthiaSays, EvalAccess, FAE, MAGENTA, OCAWA, TAW, WAVE, WebAcc Checker | Low vision, color blindness, Blind, deaf, dyslexia, cognitive, mobility impairments | 45 | India Universities websites |
| [40] | Manual Evaluation | HCI, Questionnaires | Visual | 33 | Students school |
| [41] | Automatic Evaluation Tools | Bobby, AChecker | ..... | 51 | Special Education Departmental websites |
| [42] | Automatic Evaluation Tools | WAVE, Colour Contrast Analyser, W3C Markup Validation Service, W3C CSS Validation Service, AChecker, Etre accessibility check, Accessibility colour wheel, Accessibility Wizard | Blindness and low vision, deafness and hearing loss, learning disabilities, cognitive limitations, limited movement, speech disabilities, photosensitivity and combinations of these | 31 | Edith Cowan University (ECU) Library websites |
| [43] | Automatic Evaluation Tools | WAVE | Visually impaired people | 18 | Universities websites (6 UK, 6 Jordan, and 6 Arab region) |
| [44] | Automatic and Manual Evaluation | AChecker, Functional Accessibility Evaluator, Total Validator | ..... | 5 | Web pages of the Learning Management System eCampus |
| [45] | Automatic and Manual Evaluation | Siteimprove, HiSoftware Compliance Sheriff, JAWS | Visual | 10,000 | Penn State University Libraries websites |
| [46] | Automatic Evaluation Tools | WAVE, AChecker | ..... | 20 | Malaysian public universities |
| [47] | Automatic Evaluation Tools | AChecker | ..... | 24 | United States universities |
| [48] | Automatic and Manual Evaluation | CynthiaSays | Blind users | 12 | Palestinian university websites |
| [49] | Automatic Evaluation Tools | Fujitsu Web Accessibility Inspector, EvalAccess 2.0 | Blindness, low vision, deafness, and hard of hearing | 1 | Sultan Qaboos University website |
| [50] | Automatic Evaluation Tools | TAW, WAVE, EIII Page Checker | ..... | 38 | Higher education institution websites of Cyprus Island |
| [51] | Automatic Evaluation Tools | EvalAccess 2.0 | ..... | 42 | University website in the Kyrgyz Republic |
| [52] | Automatic Evaluation Tools | WAVE | ..... | 348 | Universities websites in Latin American |
| [53] | Automatic Evaluation Tools | WAVE | Blind and visually impaired students | 9 | University of Haifa's website |
| [54] | Manual Evaluation | JAWS, 2-switch | Visual impairment, hearing impairment, physical disabilities, dyslexia | ..... | Norwegian higher education |
| [55] | Automatic Evaluation Tools | AChecker, WAVE, aXe | ..... | 59 | Websites of Polytechnic Institutes and Universities of Portugal |
| [56] | Automatic Evaluation Tools | TAW, aXe | ..... | 44 | College websites affiliated with the University of Kashmir and Cluster University Srinagar |
| [57] | Automatic Evaluation Tools | TENON | ..... | 325 | Websites United States Institutions of Higher Education |
| [58] | Automatic Evaluation Tools | AChecker | ..... | 24 | Special education cooperative websites |
| [59] | Automatic Evaluation Tools | AChecker, Webpage Analyzer, WAVE | ..... | 40 | Universities websites in Latin American |

Information not provided is marked as "....."

**TABLE 10.** Data extracted for RQ7.

| Paper | RQ7 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | WCAG 1.0 | | | WCAG 2.0 or WCAG 2.1 | | | | Conformance Level | | |
| | Priority 1 | Priority 2 | Priority 3 | Perceivable | Operable | Understandable | Robust | A | AA | AAA |
| [35] | YES | YES | YES | NO | NO | NO | NO | NO | NO | NO |
| [36] | NO | NO | NO | YES | YES | YES | YES | YES | YES | YES |
| [37] | YES | YES | YES | NO | NO | NO | NO | NO | NO | NO |
| [38] | NO | NO | NO | YES | YES | YES | YES | YES | NO | NO |
| [39] | NO | NO | NO | YES | YES | YES | YES | YES | NO | NO |
| [40] | NO | NO | NO | YES | YES | YES | YES | NO | NO | NO |
| [41] | YES | YES | YES | NO | NO | NO | NO | NO | NO | NO |
| [42] | NO | NO | NO | YES | YES | YES | YES | YES | YES | YES |
| [43] | NO | NO | NO | YES | YES | YES | YES | NO | NO | NO |
| [44] | NO | NO | NO | YES | YES | YES | YES | YES | NO | NO |
| [45] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [46] | NO | NO | NO | YES | YES | YES | YES | YES | NO | NO |
| [47] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [48] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [49] | YES | YES | YES | NO | NO | NO | NO | NO | YES | NO |
| [50] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [51] | YES | YES | YES | NO | NO | NO | NO | NO | NO | YES |
| [52] | NO | NO | NO | YES | YES | YES | YES | YES | NO | NO |
| [53] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [54] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [55] | NO | NO | NO | YES | YES | YES | YES | NO | YES | NO |
| [56] | NO | NO | NO | YES | YES | YES | YES | YES | YES | YES |
| [57] | NO | NO | NO | YES | YES | YES | YES | YES | YES | NO |
| [58] | NO | NO | NO | YES | YES | YES | YES | YES | YES | NO |
| [59] | NO | NO | NO | YES | YES | YES | YES | YES | NO | NO |

of inclusion, exclusion and quality assessment, the number of papers was reduced to 25.

In terms of the number of papers selected in this SLR, it is clear that the United States is the country with the most publications in the subject of web accessibility of educational websites. However, countries such as Ecuador, India, Malaysia, Portugal, Slovenia, Spain, Australia, Israel, Italy, Jordan, Norway, Kyrgyz Republic, Sultanate of Oman and Turkey have also published papers on the accessibility of educational websites, albeit in smaller quantities. The small number of research papers in mention countries may be the result of research limitations and should not be directly related to a lack of interest.

Of the 25 selected papers, 19 use WCAG 2.0 to evaluate educational websites. Of the 19 papers, 13 use WCAG 2.0, 4 use WCAG 2.0 and Section 508, 1 uses WCAG 2.0 and ISO/IEC 24751 and 1 uses WCAG 2.0 and SI 5568. Of the remaining 5 papers, 3 use WCAG 1.0 and Section 508, 1 uses WCAG 1.0 and 1 uses WCAG 2.1. In summary, all selected papers evaluate educational websites using the WCAG, which is the purpose of this SLR.

Education is in an evolutionary process that adjusts to laws, regulations and the new demands of teaching and learning [69]. A key aspect is the inclusion and participation of all persons in the educational environment, as required by article 24 Education of the Convention on the Rights of Persons with Disabilities [8]. The results of the SLR show that web accessibility standards are not met on the educational websites analyzed in the papers. The websites analyzed in the 25 papers pose significant barriers for people with disabilities. Therefore, web accessibility issues violate the legal rights of people with disabilities, who can sue websites according to the laws and regulations in force in each country. The challenge for educational institutions is to undertake projects to comply with web accessibility standards and other current laws of educational inclusion. Bearing in mind that, in education, accessibility contributes to creating better opportunities for students. One of them is that students with disabilities are more likely to complete their studies and get a job. Today,

**TABLE 11.** Data extracted for RQ8 and RQ9.

| Paper | RQ8 | | | RQ9 | |
|---|---|---|---|---|---|
| | Real users | # Users | # Experts | Errors from Tables 12 and 13 | Accessibility Guidelines |
| [35] | NO | ..... | ..... | 1.1, 1.5, 3.2, 3.4, 3.5, 4.3, 5.5, 6.2, 6.5, 7.2, 7.3, 7.4, 7.5, 9.3, 10.4, 10.5, 12.1, 12.4, 13.1, 13.2 | WCAG 1.0 |
| [36] | NO | ..... | ..... | Does not specify errors | WCAG 2.0 |
| [37] | NO | ..... | ..... | 1.1, 12.1 | WCAG 1.0 |
| [38] | NO | ..... | ..... | 1.1.1, 1.3.1, 2.1.1, 2.2.1, 2.2.2, 2.4.2, 2.4.4, 3.1.1, 3.3.2, 4.1.1, 4.1.2 | WCAG 2.0 |
| [39] | NO | ..... | ..... | 1.1.1 | WCAG 2.0 |
| [40] | YES | 33 Students | ..... | 3.1.1 | WCAG 2.0 |
| [41] | NO | ..... | ..... | 1.1, 4.3, 5.5, 6.4, 10.2, 10.5, 13.1 | WCAG 1.0 |
| [42] | NO | ..... | ..... | 1.1.1, 1.3.1, 1.3.2, 1.4.1, 1.4.3, 1.4.4, 1.4.5, 1.4.6, 1.4.8, 2.1.1, 2.1.2, 2.1.3, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 3.2.1, 3.2.2, 3.2.5, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.6, 4.1.1, 4.1.2 | WCAG 2.0 |
| [43] | NO | ..... | ..... | 1.1.1, 1.3.1, 2.4.2, 2.4.4 | WCAG 2.0 |
| [44] | YES | 12 Students | 2 Usability | 1.1.1, 1.3.1, 2.4.6, 3.1.1 | WCAG 2.0 |
| [45] | YES | ..... | 1 JAWS | 1.1.1, 1.3.1 | WCAG 2.0 |
| [46] | NO | ..... | ..... | 1.3.1, 1.4.1, 1.4.2, 1.4.3, 1.4.4, 1.4.5, 1.4.6, 1.4.8, 2.1.1, 2.1.2, 2.1.3, 2.2.1, 2.2.2, 2.2.3, 2.2.4, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 2.4.6, 3.1.1, 3.1.2, 3.3.1, 3.3.2, 3.3.3, 3.3.4, 3.3.5, 3.3.6, 4.1.1, 4.1.2 | WCAG 2.0 |
| [47] | NO | ..... | ..... | 1.1.1, 1.4.3, 2.4.10, 3.1.1, 3.3.2 | WCAG 2.0 |
| [48] | YES | 16 Blind users | ..... | 1.3.1 | WCAG 2.0 |
| [49] | NO | ..... | ..... | 1.2, 1.5, 12.1, 12.4, 13.8 | WCAG 1.0 |
| [50] | NO | ..... | ..... | 1.4.3 | WCAG 2.0 |
| [51] | NO | ..... | ..... | 1.1, 8.1 | WCAG 1.0 |
| [52] | NO | ..... | ..... | 1.1.1, 2.4.4 | WCAG 2.0 |
| [53] | NO | ..... | ..... | 1.1.1, 1.3.1, 1.3.2, 1.4.3, 2.1.1, 2.2.1, 2.2.2, 2.4.1, 2.4.2, 3.1.1 | WCAG 2.0 |
| [54] | YES | Anonymous users | ..... | 1.1.1, 1.3.1, 1.3.3, 1.4.1, 1.4.2, 1.4.3, 1.4.4, 1.4.5, 1.4.6, 2.1.1, 2.1.2, 2.2.1, 2.2.2, 2.3.1, 2.4.2, 2.4.3, 2.4.4, 2.4.5, 3.1.1, 3.1.2, 3.3.2, 3.3.3, 3.3.6, 4.1.1, 4.1.2 | WCAG 2.0 |
| [55] | NO | ..... | ..... | 1.1.1, 1.3.1, 1.4.1, 1.4.3, 1.4.4, 1.4.5, 2.4.6, 2.4.9 | WCAG 2.0 |
| [56] | NO | ..... | ..... | 1.1.1, 1.2.2, 1.2.5, 1.4.1, 2.4.6 | WCAG 2.0 |
| [57] | NO | ..... | ..... | 1.1.1, 1.3.1, 1.3.2, 1.4.5, 2.1.1, 2.3.1, 2.4.1, 2.4.2, 2.4.3, 2.4.4, 2.4.6, 3.1.1, 4.1.1, 4.1.2 | WCAG 2.0 |
| [58] | NO | ..... | ..... | 1.1.1, 1.3.1, 1.4.1, 1.4.3, 1.4.4, 2.4.6 | WCAG 2.0 |
| [59] | NO | ..... | ..... | 1.1.1, 1.4.1, 1.4.4, 2.1.1, 2.1.2 | WCAG 2.1 |

Information not provided is marked as "....."

accessibility is no longer an option on educational websites, but an obligation that must be addressed. Basic, middle and higher education institutions, whether public or private, must comply with accessibility standards. Fortunately, there is a wealth of information and automated tools that help evaluate and correct accessibility barriers.

We are going through a time of technological changes and new paradigms of teaching-learning. From the field of education there are numerous questions, supported by empirical studies, about the transformation of the teaching-learning process with technology. This brings with it the possibility of greater demands and increased accessibility of educational websites.

This review can support researchers and developers in choosing an appropriate mechanism for developing accessible websites. In addition, the results obtained can be applied to improve the websites that have been analyzed in the papers. The WCAG has come a long way. However, developers must work more closely with the WCAG to improve the accessibility and usability of educational websites. In addition, self-governments must adopt web accessibility standards and create regulations to monitor compliance. Bearing in

**TABLE 12.** Errors by priorities and success criteria WCAG 1.0.

| Priorities WCAG 1.0 [19] | Error papers |
|---|---|
| **Priority 1** | |
| 1.1 Provide a text equivalent for every non-text element (e.g., via "alt", "longdesc", or in element content). This includes: images, graphical representations of text (including symbols), image map regions, animations (e.g., animated GIFs), applets and programmatic objects, ascii art, frames, scripts, images used as list bullets, spacers, graphical buttons, sounds (played with or without user interaction), stand-alone audio files, audio tracks of video, and video. | [35], [37], [41], [51] |
| 1.2 Provide redundant text links for each active region of a server-side image map. | [49] |
| 6.2 Ensure that equivalents for dynamic content are updated when the dynamic content changes. | [35] |
| 12.1 Title each frame to facilitate frame identification and navigation. | [35], [37], [49] |
| **Priority 2** | |
| 3.2 Create documents that validate to published formal grammars. | [35] |
| 3.4 Use relative rather than absolute units in markup language attribute values and style sheet property values. | [35] |
| 3.5 Use header elements to convey document structure and use them according to specification. | [35] |
| 6.4 For scripts and applets, ensure that event handlers are input device-independent. | [41] |
| 6.5 Ensure that dynamic content is accessible or provide an alternative presentation or page. | [35] |
| 7.2 Until user agents allow users to control blinking, avoid causing content to blink (i.e., change presentation at a regular rate, such as turning on and off). | [35] |
| 7.3 Until user agents allow users to freeze moving content, avoid movement in pages. | [35] |
| 7.4 Until user agents provide the ability to stop the refresh, do not create periodically auto-refreshing pages. | [35] |
| 7.5 Until user agents provide the ability to stop auto-redirect, do not use markup to redirect pages automatically. Instead, configure the server to perform redirects. | [35] |
| 8.1 Make programmatic elements such as scripts and applets directly accessible or compatible with assistive technologies. | [51] |
| 9.3 For scripts, specify logical event handlers rather than device-dependent event handlers. | [35] |
| 10.2 Until user agents support explicit associations between labels and form controls, for all form controls with implicitly associated labels, ensure that the label is properly positioned. | [41] |
| 12.4 Associate labels explicitly with their controls. | [35], [49] |
| 13.1 Clearly identify the target of each link. | [35], [41] |
| 13.2 Provide metadata to add semantic information to pages and websites. | [35] |
| 13.8 Place distinguishing information at the beginning of headings, paragraphs, lists, etc. | [49] |
| **Priority 3** | |
| 1.5 Until user agents render text equivalents for client-side image map links, provide redundant text links for each active region of a client-side image map. | [35], [49] |
| 4.3 Identify the primary natural language of a document. | [35], [41] |
| 5.5 Provide summaries for tables. | [35], [41] |
| 10.4 Until user agents handle empty controls correctly, include default, place-holding characters in edit boxes and text areas. | [35] |
| 10.5 Until user agents (including assistive technologies) render adjacent links distinctly, include non-link, printable characters (surrounded by spaces) between adjacent links. | [35], [41] |

mind that education is everyone's right, educational websites should be accessible to ensure equal access for people with disabilities. Much work needs to be done on education and dissemination of web accessibility to address its problems and effects on society.

Future work should continue to analyze the evolution of websites in terms of compliance with WCAG 2.1. It is recommended that templates be developed for educational websites that comply with each country's standards, regulations and laws for web accessibility and educational inclusion and their implementation. In addition, researchers should continue to evaluate websites to see if they are being updated with recommendations from new versions of the WCAG. The European Digital Agenda has published a new directive, which requires web accessibility for public sector bodies by September 2020. This will require large-scale evaluation of the accessibility of websites [70].

## APPENDIX A
## DATA EXTRACTED

See Tables 7–11.

## APPENDIX B
## ERRORS

See Tables 12–14.

**TABLE 13.** Errors in the principles, guidelines and success criteria of WCAG 2.0 and WCAG 2.1.

| Principles WCAG 2.0 [71] | Level | Error papers |
|---|---|---|
| **1 Principle: Perceivable** | | |
| Guideline 1.1 Text Alternatives | | |
| 1.1.1 Non-text Content | A | [38], [39], [42], [43], [44], [45], [47], [52], [53], [54], [55], [56], [57], [58], [59] |
| Guideline 1.2 Time-based Media: Provide alternatives for time-based media | | |
| 1.2.2 Captions (Pre-recorded) | A | [56] |
| 1.2.5 Audio Description (Pre-recorded) | AA | [56] |
| Guideline 1.3 Adaptable: Create content that can be presented in different ways (for example simpler layout) without losing information or structure | | |
| 1.3.1 Info and Relationship | A | [38], [42], [43], [44], [45], [46], [48], [53], [54], [55], [57], [58] |
| 1.3.2 Meaningful Sequence | A | [42], [53], [57] |
| 1.3.3 Sensory Characteristics | A | [54] |
| Guideline 1.4 Distinguishable: Make it easier for users to see and hear content including separating foreground from background | | |
| 1.4.1 Use of Color | A | [42], [46], [54], [55], [56], [58], [59] |
| 1.4.2 Audio Control | A | [46], [54] |
| 1.4.3 Contrast (Minimum) | AA | [42], [46], [47], [50], [53], [54], [55], [58] |
| 1.4.4 Resize Text | AA | [42], [46], [54], [55], [58], [59] |
| 1.4.5 Images of Text | AA | [42], [46], [54], [55], [57] |
| 1.4.6 Contrast (Enhanced) | AAA | [42], [46], [54] |
| 1.4.8 Visual Presentation | AAA | [42], [46] |
| **2 Principle: Operable** | | |
| Guideline 2.1 Keyboard Accessible: Make all functionality available from a keyboard | | |
| 2.1.1 Keyboard | A | [38], [42], [46], [53], [54], [57], [59] |
| 2.1.2 No Keyboard Trap | A | [42], [46], [54], [59] |
| 2.1.3 Keyboard (No Exception) | AAA | [42], [46] |
| Guideline 2.2 Enough Time: Provide users enough time to read and use content | | |
| 2.2.1 Timing Adjustable | A | [38], [42], [46], [53], [54] |
| 2.2.2 Pause, Stop, Hide | A | [38], [42], [46], [53], [54] |
| 2.2.3 No Timing | AAA | [42], [46] |
| 2.2.4 Interruptions | AAA | [42], [46] |
| Guideline 2.3 Seizures: Do not design content in a way that is known to cause seizures | | |
| 2.3.1 Three Flashes or Below Threshold | A | [54], [57] |
| Guideline 2.4 Navigable: Provide ways to help users navigate, find content and determine where they are | | |
| 2.4.1 Bypass Blocks | A | [46], [53], [57] |
| 2.4.2 Page Titled | A | [38], [43], [46], [53], [54], [57] |
| 2.4.3 Focus Order | A | [46], [54], [57] |
| 2.4.4 Link Purpose (In Context) | A | [38], [43], [46], [52], [54], [57] |
| 2.4.5 Multiple Ways | AA | [46], [54] |
| 2.4.6 Headings and Labels | AA | [44], [46], [56], [55], [57], [58] |
| 2.4.9 Link Purpose (Link only) | AAA | [55] |
| 2.4.10 Section Headings | AAA | [47] |
| **3 Principle: Understandable** | | |
| Guideline 3.1 Readable: Make text content readable and understandable | | |
| 3.1.1 Language of Page | A | [38], [40], [44], [46], [47], [53], [54], [57] |
| 3.1.2 Language of Parts | AA | [46], [54] |
| Guideline 3.2 Predictable: Make web pages appear and operate in predictable ways | | |
| 3.2.1 On Focus | A | [42] |
| 3.2.2 On Input | A | [42] |
| 3.2.5 Change on Request | AAA | [42] |
| Guideline 3.3 Input Assistance: Help users avoid and correct mistakes | | |
| 3.3.1 Error Identification | A | [42], [46] |
| 3.3.2 Labels or Instructions | A | [38], [42], [46], [47], [54] |
| 3.3.3 Error Suggestion | AA | [42], [46], [54] |
| 3.3.4 Error Prevention (Legal, Financial, Data) | AA | [42], [46] |
| 3.3.5 Help | AAA | [42], [46] |
| 3.3.6 Error Prevention (All) | AAA | [42], [46], [54] |
| **4 Principle: Robust** | | |
| Guideline 4.1 Compatible: Maximize compatibility with current and future user agents, including assistive technologies | | |
| 4.1.1 Parsing | A | [38], [42], [46], [54], [57] |
| 4.1.2 Name, Role, Value | A | [38], [42], [46], [54], [57] |

**TABLE 14.** Users who will benefit from correcting errors found in the WCAG 2.0 and 2.1 success criteria.

| Principles, guidelines and success criteria | User Groups |
|---|---|
| **Principle 1: Perceivable** | |
| Guideline 1.1 Text Alternatives | |
| 1.1.1 Non-text Content (A) | Blind, deaf, deaf-blind |
| Guideline 1.2 Time-based Media | |
| 1.2.2 Captions (Pre-recorded) (A) | Deaf |
| 1.2.5 Audio Description (Pre-recorded) (AA) | Blind, low vision, cognitive limitations |
| Guideline 1.3 Adaptable | |
| 1.3.1 Info and Relationships (A) | Blind, deaf-blind |
| 1.3.2 Meaningful Sequence (A) | Blind |
| 1.3.3 Sensory Characteristics (A) | Blind, low vision |
| Guideline 1.4 Distinguishable | |
| 1.4.1 Use of Colour (A) | Low vision, color-blindness |
| 1.4.2 Audio Control (A) | Blind |
| 1.4.3 Contrast (Minimum) (AA) | Low vision, color vision deficiency, see no color |
| 1.4.4 Resize Text (AA) | Low vision |
| 1.4.5 Images of Text (AA) | Low vision, visual tracking problems, cognitive disabilities |
| 1.4.6 Contrast (Enhanced) (AAA) | Low vision, color vision deficiency, see no color |
| 1.4.8 Visual Presentation (AAA) | Low vision, cognitive, language and learning disabilities |
| **Principle 2: Operable** | |
| Guideline 2.1 Keyboard Accessible | |
| 2.1.1 Keyboard (A) | Blind, low vision, hand tremors |
| 2.1.2 No Keyboard Trap (A) | Blind, physical |
| 2.1.3 Keyboard (No Exception) (AAA) | Blind, low vision |
| Guideline 2.2 Enough Time | |
| 2.2.1 Timing Adjustable (A) | Physical disabilities, low vision, blind, deaf, reading disabilities, cognitive or language limitations, learning disabilities |
| 2.2.2 Pause, Stop, Hide | Deaf |
| 2.2.3 No Timing (AAA) | Physical disabilities, low vision, blind, deaf, cognitive or language limitations |
| 2.2.4 Interruptions (AAA) | Low vision, attention deficit disorders |
| Guideline 2.3 Seizures and Physical Reactions | |
| 2.3.1 Three Flashes or Below (A) | Photosensitive epilepsy, photosensitive seizure disorders |
| Guideline 2.4 Navigable | |
| 2.4.1 Bypass Blocks (A) | Blind, low vision, cognitive limitations |
| 2.4.2 Page Titled (A) | Visual impairments, cognitive, short-term memory, reading disabilities, severe mobility impairments |
| 2.4.3 Focus Order (A) | Mobility impairments, visual impairments, reading disabilities |
| 2.4.4 Link Purpose (In Context) (A) | Motion impairment, cognitive limitations, visual disabilities |
| 2.4.5 Multiple Ways (AA) | Visual impairments, cognitive disabilities |
| 2.4.6 Headings and Labels (AA) | Visual impairments, reading disabilities, short-term memory |
| 2.4.9 Section Headings (AAA) | Blind, learning disabilities |
| 2.4.10 Focus Visible (Enhanced) (AA) | Attention limitations, short term memory limitations |
| **Principle 3: Understandable** | |
| Guideline 3.1 Readable | |
| 3.1.1 Language of Page (A) | Blind, reading disabilities, cognitive disabilities, language and learning disabilities |
| 3.1.2 Language of Parts (AA) | Blind, reading disabilities, cognitive disabilities, language and learning disabilities |
| Guideline 3.2 Predictable | |
| 3.2.1 On Focus (A) | Visual disabilities, cognitive limitations, motor impairments |
| 3.2.2 On Input (A) | Blind, low vision, reading disabilities, intellectual disabilities |
| 3.2.5 Change on Request (AAA) | Blind, low vision, reading disabilities, intellectual disabilities, difficulty interpreting visual, cognitive limitations |
| Guideline 3.3 Input Assistance | |
| 3.3.1 Error Identification (A) | Blind, colorblind, cognitive disabilities, language disabilities, learning disabilities |
| 3.3.2 Labels or Instructions (A) | Cognitive disabilities, language disabilities, learning disabilities |
| 3.3.3 Error Suggestion (AA) | Learning disabilities, blind, impaired vision, motion impairment |
| 3.3.4 Error Prevention (Legal, Financial, Data) (AA) | All disabilities |
| 3.3.5 Help (AAA) | Writing disabilities, reading disabilities, intellectual disabilities |
| 3.3.6 Error Prevention (All) (AAA) | All disabilities |
| **Principle 4: Robust** | |
| Guideline 4.1 Compatible | |
| 4.1.1 Parsing (A) | All disabilities |
| 4.1.2 Name, Role, Value (A) | Blind |

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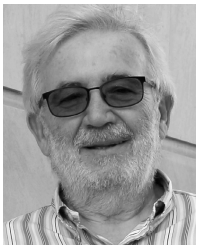

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