Universal Access in the Information Society
https://doi.org/10.1007/s10209-021-00851-x

LONG PAPER

The use of accessibility metadata in e-learning environments: a systematic literature review

Paola Ingavélez-Guerra[1] · Salvador Otón-Tortosa[1] · José Hilera-González[1] · Mary Sánchez-Gordón[1]

Accepted: 2 November 2021

Abstract
E-learning environments constitute an essential element in education, as they help students to ensure their pass their courses and graduate on time. Although guidelines, techniques, and methods have been presented in some literature in recent years to contribute to the development of accessible e-learning environments that promote digital inclusion, their implementation is challenging. In this context, the use of accessibility metadata not only provides a way to enhance the description of adapted educational resources but also facilitates their search according to the needs and preferences of students, in particular those with disabilities. In this paper, a systematic review was conducted in order to provide the state of the art regarding the use of accessibility metadata in e-learning environments. A total of 746 documents were found during the period from 2012 to 2019, of which 31 were selected according to the inclusion and exclusion criteria relevant to our review. The findings revealed an intensive use of models and standards of accessibility in e-learning environments, however, using accessibility metadata remains underused. In fact, the evaluation of accessibility and adaptability through the use of its metadata was not found. The findings obtained also helped to establish challenges and opportunities in this research field as well as to provide an overview that could support those who generate educational resources to keep their interest in making them accessible.

Keywords Adaptive systems · Distance learning · Educational technology · Metadata

1 Introduction

The development of technology and its application in education is a continuous study of ever more versatile innovations. However, it is necessary to establish an evaluation that supports the whole process, both pedagogical and technological [1]. Several institutions and countries have worked to establish accreditation and quality systems in e-learning environments according to their needs. For instance, [2] point out how several countries establish a variety of approaches on distance education in Asia to create a culture of quality based on top-down processes. In this way, those approaches aim at building the capacity of professionals to take ownership, as well as building sustainable commitment among professionals [3]. In this scenario, accessibility is an important issue that must be seen transversally in several areas such as educational, social, and cultural [4]. Accessibility, disability, and inclusion are related in some ways, for instance, ethical (thinking beyond oneself), social (reaching a wider audience by contributing to diversity), political (being active participants in society), and economic (losing potential customers) [5]. Regarding disability, around 1000 million people worldwide, i.e., 15% of the world's population, have a disability of any kind, and their incidence is higher in developing countries [6]. As the structures for health care, rehabilitation and education focused on student diversity are not completely developed, it can be said that trend is negative. Consequently, there is a need to have processes of evaluation that favor educational inclusion.

Today, countries have the challenge of providing quality education for all, strengthening the approach to inclusion, facing high rates of exclusion, discrimination, and educational inequality [7]. The Convention on the Rights of Persons with Disabilities and Optional Protocol states in article 24: "The States Parties recognize the right of persons with disabilities to education. With a view to making this right effective without discrimination and on the basis of equal opportunities, the States Parties will ensure an inclusive education system at all levels as well as lifelong

✉ Paola Ingavélez-Guerra
pcingavelez@ups.edu.ec

[1] Universidad Politécnica Salesiana, Cuenca, Ecuador

Published online: 20 December 2021

education." UNESCO in the Paris Declaration in 2012 recommends member states "to promote the quality, assurance and peer review of OERs (Open Educational Resources). To encourage the development of mechanisms for the evaluation and certification of learning outcomes obtained through the OER." In 2015, the world forum on education also reaffirmed its commitment to "education for all" with the Incheon Declaration and the Education 2030 Framework for Action. The Incheon Declaration [8] states that "inclusion and equity in and through education is the cornerstone for a transformative education agenda" and that "no education target should be considered met unless it is met by all." Therefore, there is a need to focus on evaluation processes that promote educational inclusion. In this context, technology is a key element in online learning and e-learning environments. E-learning contains various digital resources such as texts, videos, animated graphics, interactive activities, simulations, audio files, downloadable documents, evaluation tests, communication tools, among others. The courses are usually integrated into educational platforms such as learning management systems (LMS) that allow students to access all the resources and administrators of these platforms in order to manage, train and follow the evolution and progress of their learners [9].

According to the ISO/IEC 25000 System and Software Quality Requirements and Evaluation (SQuaRE) series of standards, accessibility is an important characteristic to evaluate the quality of software products [10]. Since the teaching-learning process goes beyond the technological use of tools, it is necessary to understand the synergy that must exist between technology and methodological design to establish an innovative and quality teaching model, considering ubiquitous computing and its relationship with many simultaneous devices and systems.

In this sense, accessible e-learning is becoming a key issue in order to ensure full inclusion of people with disabilities. Accessibility metadata can improve OER adaptability by describing accessibility of resources and services available on e-learning environment. To our knowledge, this is the first study to examine the impact of accessibility metadata in e-learning environments across academic literature. Thus, the main contribution of this work is to systematically review the relevant literature about this topic, considering accessibility metadata as one of the ways to address possible discrimination against students with disabilities. The Research Objectives (RO) of this study are the following:

RO1: To identify the use of accessibility metadata in e-learning.
RO2: To determine the most common standards applied in the application of accessibility metadata.
RO3: To identify challenges and opportunities of accessibility and adaptability in e-learning.

This study is organized as follows. In Sect. 2, the background is presented. In Sect. 3, the research methodology is outlined. In Sect. 4, an analysis of the results is given, while in Sect. 5, the discussion and recommendations are provided. Finally, in Sect. 6, the main conclusions of this study are presented.

2 Background

2.1 Accessibility and adaptability

Accessibility and adaptability are two terms that converge when it comes to addressing the diversity of human beings (adaptability), seeking to provide flexibility in its environment (accessibility), so that it adapts to each user's needs and preferences. The standard ISO/IEC 24751-2:2008 Information technology—Individualized adaptability and accessibility in e-learning, education, and training, defines accessibility as "usability of a product, service, environment or installation by individuals with the broadest spectrum of skills possible," and adaptability as "ability of a digital resource or a delivery system to adjust the presentation, control methods, structure, access mode, and user support, in its presentation" [11]. Accessibility relates to several concepts that seek to facilitate the development or use of something in particular, including flexibility, customization, universality, usability, interoperability, reusability, and navigability.

It is worth noting that there are people who, even if they do not have a permanent or temporary disability, they face difficulties with information access. Thus, many accessibility requirements improve usability for everybody, especially in limiting situations. For example, providing sufficient color contrast benefits people using the web on a mobile device in bright sunlight or in a dark room. In noisy and in quiet environments such as emergency rooms and libraries, captions benefit people. Indeed, older adults have functional limitations due to natural aging and may not identify these as a "disability." These situations are addressed by accessibility as well.

The W3C accessibility standard, known as WCAG, constitutes the most significant contribution to web accessibility. Its relationship with accessibility metadata in educational resources is not direct. A digital educational resource focuses on several educational fields; however, the interoperability analysis of a resource is enriched by WCAG conformance criteria.

2.2 Learning object and open educational resources

A learning object (LO) could be understood as any digital multimedia resource used in virtual learning environments.

It is also known as an e-learning training resource. LO has the purpose of integrating a sharable knowledge into an educational environment; therefore, it must meet certain characteristics that facilitate its reuse and interoperability. Rodriguez-Ascaso et al. [12] indicate important characteristics on the definition of an open educational resource and its relationship with the legal frameworks on open licenses. The contents can be learning objects or courses. A course can be MOOC (Massive Open Online Courses) or OCW (Open Course Ware) that usually belongs to an institution [13].

2.3 Models and standards

Initially, resources were integrated with the code of each platform. Accordingly, the educational course administrator software, known as LMS, comes from the concept of e-learning. Each platform could establish its guidelines responding to traditional development models of distance education at a regional or institutional level. Thus, one can find models of evaluation, educational/pedagogical, platforms, learning, and business among others. In the first generation of e-learning models, the ADDIE model emerged [14] focused on the main technique of instructional design. Later, it was called Rapid E-learning [15] enhancing the author's tools. Given that several models of evaluation of quality of virtual learning [3, 16] and international comparative studies [17] establish their foundations on the experiences of the pedagogical process, it is worth mentioning that among their indicators and evaluation criteria, they consider accessibility as a relevant indicator. However, accessibility is considered as a disposition of the technological resource 24 h 365 days a year.

In conducting the literature review, more than 70 quality models related to e-learning were found, but only 30 of these models consider accessibility, adaptability, and usability as relevant evaluative parameters, for instance, [9, 18–20]. The development of standards establishes rules and requirements that must be fulfilled. For example, they enable resources to be independent of the platforms, strengthening their interoperability, reuse, durability, updating, and scalability. This generates standards for many areas of e-learning [21–25].

Figure 1 depicts the different elements related to models and standards. In e-learning, the application of standards is more focused on resources and techniques, while the methodology, the method, and the model respond to particularities of each institution or region, even more they are regulated by each country.

2.4 Metadata

For the description of the accessibility characteristics of the contents published in learning objects, it is necessary to use mechanisms for the description of information based on

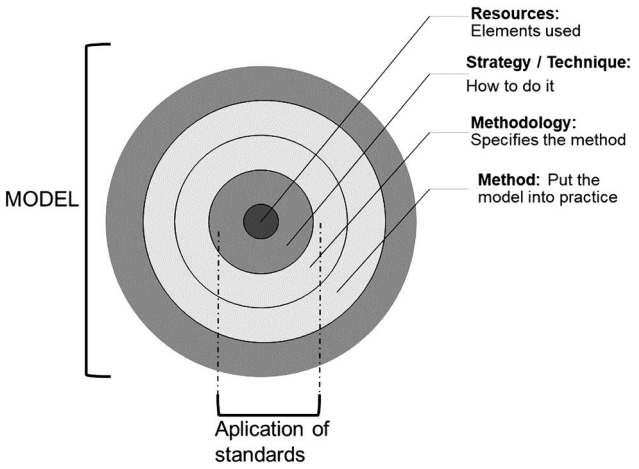

Fig. 1 Components of a model. This graph synthesizes in a layered way the different terms involved in a model and locates where standards are established

metadata. Such metadata would facilitate the information of a digital resource and its possible requirement based on preferences and needs of the student [26]. The accessibility metadata defined by Schema.org is based on IMS AfA v3.0 [27, 28] that meets the standard [11, 24]. In the case of students with disabilities, these guidelines are relevant as they contain information about their interaction. Figure 2 shows that accessibility metadata are relevant information to describe the content of a resource. The accessibility metadata can describe the accessibility characteristics of the educational resource (DRD), as well as provide information on user preferences and needs (PNP).

2.5 Related works

Some projects have been developed to promote accessibility and adaptability on virtual environments. The shared experiences of initiatives such as EU4ALL [12], ESVIAL [29], TILE, AEGIS, ACCESSIBLE [30] in Europe and OBBA in Brazil [31], reveal research and implementation efforts to favor educational inclusion. However, the evaluation of quality in e-learning has generated proposals for models and standards, in which the accessibility criterion is considered relevant but has not yet reached an information agreement. The automated quality assessment with LOMPAD-Q [32] proposes metadata based on the evaluation of 32 virtual courses, using four different models: LORI, LOEM, ECB-Check and UNE 66181:2012. This study highlights accessibility as an important parameter to be considered in a quality evaluation; however, the way to establish it represents an extensive topic. Therefore, more accessibility research is needed. The standard [11] presents relevant information on the use of accessibility metadata [33]. The implementation of AfA 3.0 sought to socialize its applicability and

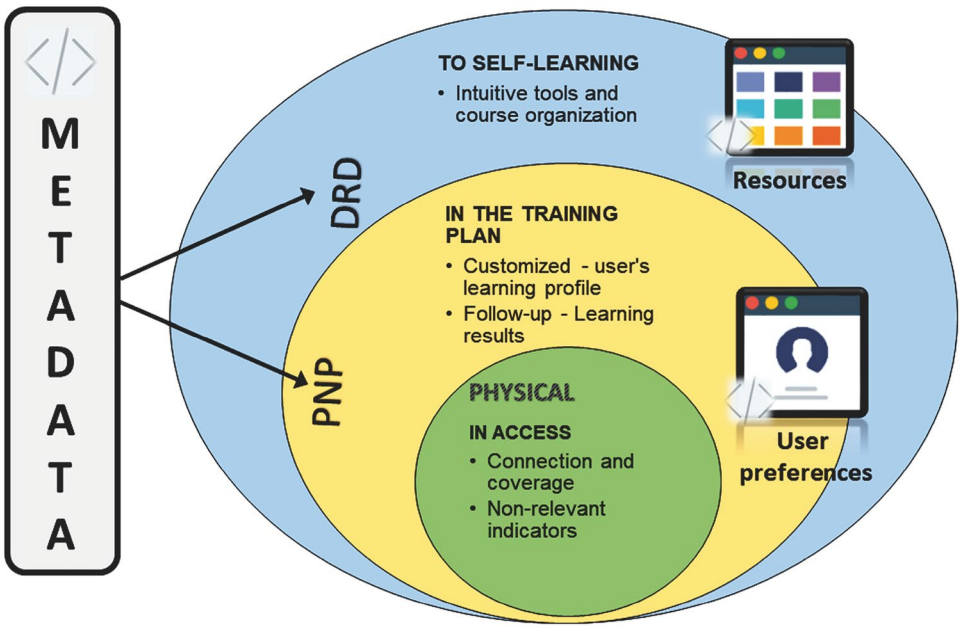

Fig. 2 Accessibility metadata. The graph presents the accessibility metadata components associated with resources and user requirements, considering ways of interaction

greater understanding, which contributes to the gradually increasing learning curve [34]. The measurement of adaptability in e-learning, according to [35], was defined with indicators for three levels: self-learning, training plan and access. However, the training plan and self-learning require a greater emphasis on adaptability in diagnostic evaluation and continues to seek superior efficacy and efficiency even in the post-training process. Experiences such as those of [36] point out the need to open pre-registration phases to know the preferences of students interested in the course, and to prepare the necessary adaptations. The importance of including personal recommendations on the use of resources is highlighted. The use of metadata in virtual environments is reduced. Navarrete and Lujan-Mora [37] made out a quantitative study based on the use of Schema metadata with emphasis on virtual education. They analyzed 4,458,312 domains from 2014 to 2016. They conclude that the use of accessibility metadata is scarce, implying a lack of technical knowledge on accessibility in the implementation of metadata in educational content. Research and contributions on the topic are significant, but not sufficiently socialized or their findings do not yet have an impact on actual implementation in the field of accessible e-learning.

3 Methodology

This systematic literature review study is based on the well-known guidelines proposed by [38], as well as the principles of the PRISMA Statement proposed by [39]. Moreover, given that a review protocol can reduce the possibility of research bias, we designed it based on [40]. Zotero was also used as reference management software, and Excel spreadsheets were employed to extract the data.

3.1 Research questions

The following research questions (RQ) were formulated based on the aforementioned research objectives (RO).

RQ1: To what extent do standards and specifications in e-learning include accessibility metadata? In order to respond to this RQ, the study analyzed relevant previous studies on accessibility metadata and the organizations that influenced its development.

RQ2: Could accessibility and adaptability in e-learning be evaluated through metadata? In order to respond to this RQ, the study analyzed the standards and specifications (rules) used in learning environments that consider accessibility criteria and metadata.

RQ3: Does accessibility metadata have any positive impact on the preferences and needs of a student with disabilities? In order to respond to this RQ, the study investigates the experiences of e-learning with people with disabilities identifying the best practices, learning outcomes and degree of satisfaction.

RQ4: What are the challenges and opportunities that have been addressed in this area of research? In order to answer this RQ, the study investigates the limitations of existing tools and systems related to accessibility metadata. It also summarizes and provides recommendations reported to overcome the limitations.

3.2 Conducting the review

3.2.1 Search strategy

The search strategy was formulated based on ROs and RQs. First, search keywords were identified. Then, the search string was formulated. The Boolean operator 'OR' was incorporated to include alternative synonyms, and then, the Boolean operator 'AND' was used to link the keywords and create the final search string. The search string formulated was as follows:

(metadata OR metadato) AND (adaptability OR accessibility) AND (e-learning OR MOOC OR "virtual learning").

After that, the search process was carried out in December 2019. To do so, five search engine databases were used: Web of Science, Scopus, Education Resources Information Center (ERIC), ACM, and IEEE Xplore. Furthermore, we used the library search engine of University of Alcalá (BUAH) that subscribes to other major academic databases such as SpringerLink, Elsevier, ProQuest Research Library and Emerald Insight. The same search string was used in each engine database.

Based on the inclusion/exclusion criteria [71], irrelevant articles were removed. Moreover, given that an article may be retrieved from more than one database, we checked and removed the duplicates. When title and abstract did not provide enough information to decide the inclusion of the article, other parts of the article were considered to make the inclusion or exclusion decision. However, if the doubt remained, the article was included, leaving the possibility to discard the paper during the next stage when the full text of the articles was studied. Therefore, full text reading of each article determined the total number of primary studies. In total, 31 primary studies that met the inclusion criteria were included. The list of studies is included in the "Appendix 1." Hereafter, each study is assigned an ID number (S01... S31) so that the reader can refer to it for further information. Figure 3 shows an overview of the different stages of the systematic literature review (SLR) process.

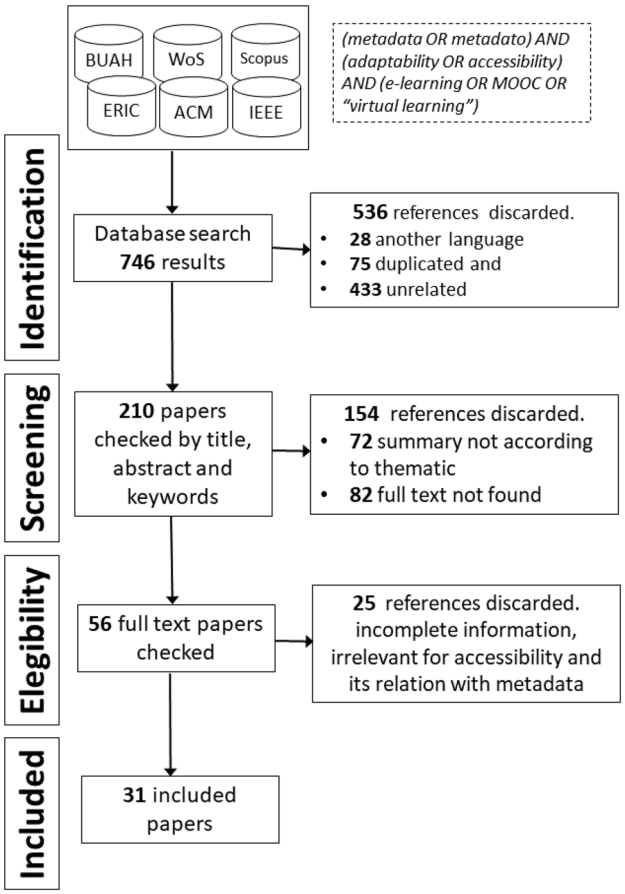

Fig. 3 Process of study selection criteria. The graph systematizes Kitchenham's [41] study scheme and the selection of criteria

3.2.2 Study selection criteria

The selection criteria were made by the authors according to the RQs. Therefore, the selection of studies was conducted by applying a set of inclusion and exclusion criteria. The inclusion criteria were as follows:

- Articles published between 2012 and 2019;
- Articles written in English and Spanish;
- Articles that integrate accessibility and metadata in virtual learning environments such as MOOC and e-learning;
- Articles accepted for publication through a peer review process.

The exclusion criteria were the following:

- Articles whose full text was not accessible;
- Articles that do not address metadata and accessibility in virtual learning environments;
- Incomplete Articles (published as Short Paper or Abstracts, less than 4 pages);
- Duplicated articles.

3.2.3 Assessment criteria for study quality

The articles selected after the exclusion and inclusion criteria were evaluated for quality, by using an evaluation checklist that was created on [41]. Moreover, krippendorff's alpha [42] was applied to measure the agreement between the two first authors of this SLR, who did the quality evaluation independently. As a result, it can be concluded that the data are interpreted in a similar and acceptable way, since the

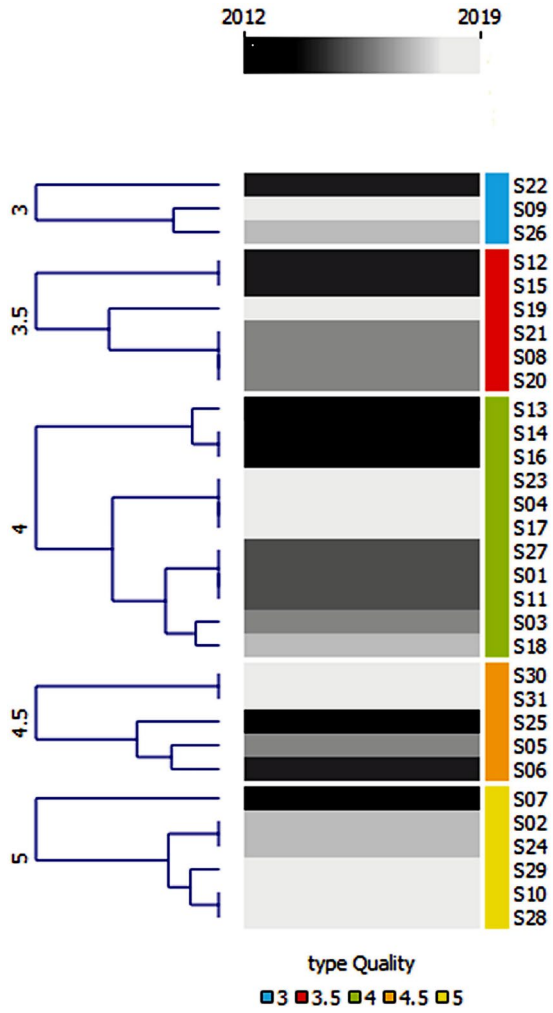

Fig. 4 Results of quality assessment. The heat map in gray tones shows the comparison of publications over the years and the quality evaluated. Studies published in 2012 are grayer as opposed to 2019 where the color tends to white. The numbers on the left of the figure show quality, the bars in the middle show the year, finally the selected studies (S01 ... S31) are grouped by the results of the quality evaluation

alpha value is 86.1%, in a sample of 85% of selected articles. The other authors contributed to raise an agreement and monitoring the process, as well as establishing the reliability of the findings and their actual representation.

3.2.4 Result of quality assessment

The checklist in "Appendix 2": Quality Assessment Checklist was used to evaluate the quality of each study. Figure 4 shows the results of the quality evaluation, data collection, and procedures that were evaluated.

The evaluation on the first criterion (QA1) shows that 29 of the studies have well-structured data collection and procedures, and only two studies presented partially clear procedures. The second criterion (QA2) examined whether the studies presented their research methodology. In 29 studies, the methodology was presented clearly and along with the type of methodology used (for example, descriptive research, empirical research, or case study). The other two studies presented their research methodology, but the details were not clear. The third criterion (QA3) examined the appropriate description of study participants or observation units. Seven studies described the participants of the study or observation unit. While the description of five articles was not clear and references were read to see more details, only one of them explicitly mentions that the details of the participants are in a previous study. In 19 studies, the participation or observation unit was not described at all. The fourth criterion (QA4) examined whether the results were clearly established. In this case, the results of 24 studies are clearly described, while the results of seven studies are partially clear. The fifth criterion (Q5) evaluates the approach and formulation of conclusions and future work. Here, the approach and formulation of conclusions and future work of 28 studies were well explained, while three studies did so partially. According to the quality assessment checklist, only six studies achieved all the criteria (the general evaluation of the document on the checklist is 'yes'). However, all of the studies raised at least 3 points of 5. Therefore, they were included in this review.

3.2.5 Data extraction and analysis

A standard information form [41] was adopted to extract data from the primary studies as previous systematic reviews did [43, 44]. The basic information was automatically extracted as provided by the libraries. Such information was title, type of publication, source, complete reference link (DOI), year of publication, and authors. Then, specific data were extracted from each primary study and were stored in an Excel spreadsheet. As mentioned before, two authors carried out the data extraction independently. In case of disagreement, consensus was reached after discussing with the third author, while the fourth author supervised the whole process so that accuracy and reliability of the process and the final results were ensured.

4 Results and analysis

The first result of our (SLR) is that only 31 studies of 746 met our selection criteria. The bibliographic details of the 31 primary studies analyzed in this SLR are presented in "Appendix 1." In what follows, the trends of primary studies are presented, followed by the main findings.

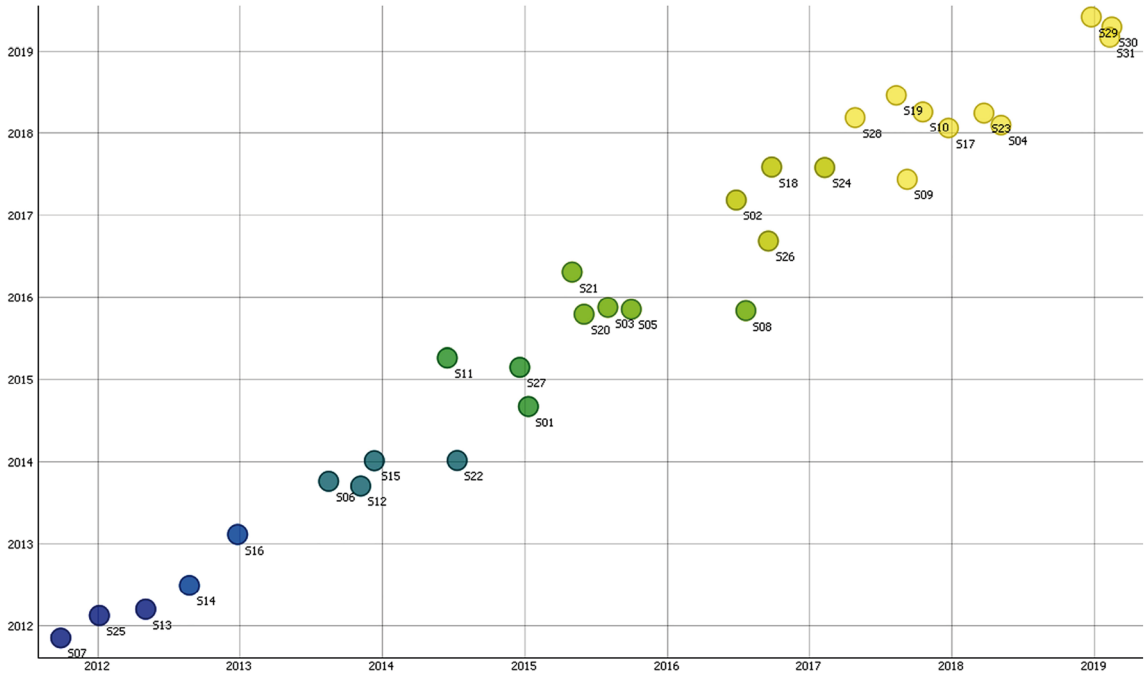

Fig. 5 Distribution of primary studies by publication year. The scatter plot shows the publications found between 2012 and 2019

Table 1 Research type and primary studies

Class	Assessment Criteria	Results (study ID)
Evaluation research	Investigation of a problem or implementation of a technique in practice	S01, S03, S05, S10, S11, S12, S14, S23, S24, S28
Validation research	Find out that the solution proposals are based on a thorough and methodologically consistent investigation	S17, S19, S22
Personal experience paper	Experience based on a project. Here, lessons learned and evidence are reported without a discussion of research methods	S02, S07, S16, S25, S26, S29
Proposal of solution	Innovative or significant solution techniques are proposed. Although, their relevance is discussed there is no complete validation	S04, S06, S08, S09, S13, S15, S18, S20, S21, S27, S30, S31

4.1 Trends of primary studies

Of all primary studies, 75% were published in scientific journals, while 25% were presented in high impact conferences. Figure 5 depicts the distribution of studies by year of publication. As can be seen, during the past few years, there appears to be a slow but growing interest in this topic. The peak year in terms of the number of papers was 2018 in which seven papers were published. The period 2016 to 2018 seems to be a period during which the local legislations established compliance with regulations about accessibility. Research about this accessibility metadata in 2019 is still sparse. On the other hand, the primary studies consisted of 24 journal articles and seven conference papers.

Table 1 shows the number of publications by type of research according to [45]. Most of the primary studies (71%, 20) were "Proposal of solution" (12) and "Evaluation research" (10), followed by "Personal experience paper" (6), and "Validation research" (3).

Finally, Table 2 shows a summary of primary studies grouped by research questions that were answered after full text reading. Therefore, the findings were grouped into four categories in order to answer the research questions.

4.2 RQ1: To what extent do standards and specifications in e-learning include accessibility metadata?

To answer this question, it is necessary to analyze relevant previous studies on accessibility and metadata. In this way, it is possible to understand how standards and specifications in e-learning include accessibility metadata. Figure 6 shows

Table 2 Summary of primary studies grouped by research questions

Research Question	#	Results (study ID)
RQ1	16	S01, S02, S04–S08, S10, S12, S15, S18, S19, S24, S28–S30
RQ2	23	S01–S07, S09–S11, S13, S14, S16–S20, S22–S24, S26, S28, S29
RQ3	14	S01, S02, S06–S08, S10, S12, S16, S18, S23, S24, S27, S29, S31
RQ4	31	S01–S31

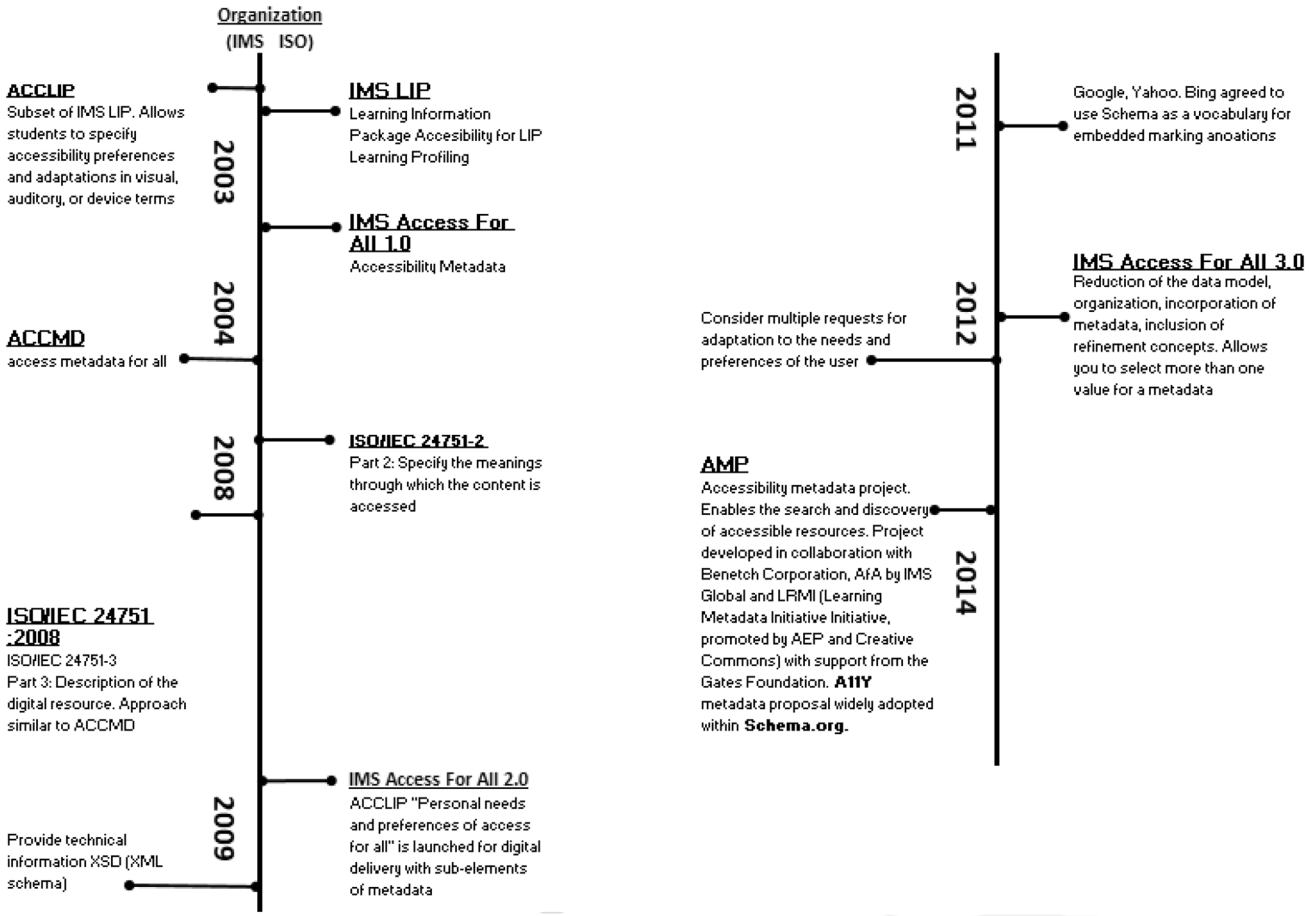

Fig. 6 Timeline of accessibility metadata. The graph shows a timeline in the history of accessibility metadata

a timeline of metadata and accessibility that allows to better understand what standards and specifications include accessibility metadata. IMS Global and ISO are the organizations that lead this subject [30, 46]. From 2003 to 2004, guidelines to support the accessibility requirements appeared [47, 36]. Thus, information profiles for IMS LIP students and its information packet for ACCLIP students were published. In 2004, a more extensive proposal called AfA 1.0 with access metadata for all (ACCMD) was proposed.

In 2008, ISO published the ISO/IEC 24751 standard. In particular, the second and the third part of it are related to this review. The second part includes metadata for preferences and user needs (PNP) [12, 48], and the third part includes the description of the resources (DRD) [49, 50]. However, those initiatives were still complex to apply in practice. In 2009, AfA 2.0 was published to provide technical information that allows the implementation of accessibility metadata. There were few efforts and initiatives of applicability of metadata that support the rules created to date. Then, in 2011, Google, Yahoo and Bing agreed to use a Schema.org specification as a common vocabulary [37]. By 2012, AfA 3.0 was proposed. This effort was made to reduce data model and organization of AfA 2.0 and to include other metadata [33, 34, 37, 51, 52]. Moreover, refinement concepts such as the selection of more than one value per metadata and the possibility of multiple adaptation requests were included. However, it is in 2014 that the accessibility metadata project (AMP) achieved a subset of accessibility

Table 3 Summary of primary studies grouped by research questions

Standards	Specifications	Study ID
IMS AfA	V 1.0, 2.0 or 3.0	S01, S02, S05, S23, S29
ISO/IEC 24751	Part 1, 2 or 3	S01, S05, S06, S23, S29
WCAG	WCAG 2.0	S04, S06, S10, S23, S29
The standard for Learning Object Metadata	IEEE LOM 1484.12.1 OBBA	S03, S11, S13, S18, S30, S31
Quality Models	LORI LOEM ECBCheck UNE 66181:2012	S03
Ergonomic of human-system interaction	ISO 9241	S10, S23
Schema.org	AMP v 6.0	S01,S04, S19, S28
LRMI	V1.0 or v1.1	S05, S23, S28
Learning education and training	ISO/IEC 19796-3	S17
Own proposals	–	S07, S11
Support metadata standardization	–	S09, S14, S16, S24, S26

metadata for search and discovery. AMP was carried out in collaboration with IMS Global along with the Learning Resource Metadata Initiative (LRMI) and the Gates Foundation. Finally, a metadata proposal called A11y was generated within Schema.org [53]. In [37], researchers summarize that the metadata of greater use and related to accessibility would be accessibilityControl (input methods with which the resource can be controlled), accessibilityFeature (accessibility features present in the resource), and accessMode (sensory access form- human perceptive). The above-mentioned metadata and its characteristics can be found on the Schema website [54].

4.3 RQ2: Could accessibility and adaptability in e-learning be evaluated through metadata?

Contributions in regulations that guide the process of implementing metadata in accessibility have been valuable. Rodriguez-Ascaso and González Boticario [36] pointed out the importance of ISO/IEC 24751 in describing the student's accessibility needs, as well as the digital resource in the guidelines of their research. Moreover, [30] and [47] justify their research with AfA 3.0 while [49, 51] base their respective proposals on the WCAG standard to suggest success criteria related to learning objects. Navarrete and Luján-Mora [55] based the evaluation of the accessibility gap in Open Educational Resources on WCAG 2.0 (identified as ISO/IEC 40500), ISO 9241-151: Guide on the user interfaces of the World Wide Web, and AfA 3.0. The different methodologies used in these studies reveal efforts to understand and apply the standards established by ISO and IMS. Adaptability, self-learning, self-organization [52, 56], personalization [57] are considered relevant to establish metadata that strengthen the search for the best educational resource for each student. In this sense, the EU4ALL project (IST-FP6-034778) developed a framework to address the needs of accessible lifelong learning at Higher Education level [50]. In fact, this project was the main reference for building the new IMS Access for All v3.0, i.e., it contributed to the development of the Accessibility Metadata Standards. An Educational Metadata Profile is proposed by [58] to characterize digital educational resources based on IEEE LOM, concluding that it is rich enough to effectively describe both the educational and technical aspects of an educational resource. The effective use of metadata demonstrates its importance in case studies such as screen readers [59]. In addition, [12] points out that having a repository of learning objects with full metadata could support the adoption of accessibility metadata systems. The generation of LOM editors facilitates the implementation and storage of metadata in the resource, with LOMPad being a freely, and widely user editor. However, accessibility metadata are not yet considered in that editor. The quality of data and metadata is still a rare practice of implementation since it involves subjective, multi-dimensional and context-dependent concepts [60]. Quantitative research on the use of accessibility metadata and limited knowledge in its implementation are addressed in the research carried out by [37]. They conclude that the most used are those that respond to general properties in terms of the pedagogical proposal. Regarding accessibility metadata itself, a single educational domain (www.bookshare.org) was found. Such domain includes accessibility features and the license of resources as a whole [53]. Therefore, it can be concluded that it is possible to evaluate the accessibility and adaptability in e-learning by the information of the metadata, which would provide valuable information of accessible resources for learners. Table 4 shows a summary of specifications and standards that consider the accessibility in the evaluation (Table 3).

4.4 RQ3: Does accessibility metadata have any positive impact on the preferences and needs of a student with disabilities?

Research that specifies a real sample of students with disabilities and their endorsement in proposed methodologies that provide solutions to the accessibility problem is still limited. Rodriguez-Ascaso and González Boticario [36] proposed a user-centered design methodology that allows the identification, through scenarios, of found problems and existing challenges. This research is based on the needs identified in a process of collecting requirements of users with and without disabilities in higher education institutions within the project EU4ALL. On the other hand, [61] identifies virtual scenarios of social learning, designs recommendations aimed at meaningful education. It also considers the generality for reuse in other scenarios with similar characteristics. Batanero et al. [51] conducted a study to establish the mandatory accessibility metadata that should be included in a learning object, considering the preferences and needs of the student (AfA PNP):

AccessMode, HasAdaptation, ControlFlexibility, DisplayTransformability, Hazard, AtInteroperable, ApiInteroperable, IsAdaptationOf, IsPartialAdaptationOf, IsFullAdaptationOf, AdaptationType, AccessModeAdapted, AdaptationDetail, AdaptationMediaType, LanguageOfAdaptation, EducationalComplexityOfAdaptation, EucationaLevelOfAdaptation.

This study is based on the interaction of underground workers, with a program that provides them with information about the type of fault or zone map. The scenario in this case is low visibility and/or high noise so they are provided with adapted Learning Object (LO), having the possibility of choosing the profile, considering sign language, animated diagrams or Braille device. Rodriguez-Ascaso et al. [50] emphasizes the needs of Accessible Lifelong Learning. It details the interaction of a team that includes five stakeholders: (1) teachers trained in design of accessible material and its monitoring, (2) students expressing their accessibility needs, (3) disability officers assessing needs, (4) transformation officers working on the adaptation of materials and (5) librarians to support the labeling and handling of learning materials in electronic repositories. Lin et al. [62] establishes the need for segmentation and annotation strategies in e-learning domains through metadata. Annotation is the basis for the accessibility and reuse of resources to search and detection of micro-learning. Koutkias et al. [48] proposes a structure that addresses student preferences and generates an environment to interact framed in universal design and inclusion. Pal et al. [63] identifies a subset of educational metadata, from IEEE LOM, for video-based e-learning materials considering that appropriate choices can be made based on the student's learning requirements, preferences, and pedagogy choice. Navarrete and Luján-Mora [55] proposed the identification of the user through login and defining a disability profile along with accessibility options for the search. They also established the need for a custom adaptive interface design considering the language. The study carried out by [33] was based on students with functional diversity. The authors concluded that a simple design allows an efficient implementation of the adapted learning platform and easy portability to other platforms for learning and storage of LO. Kearns [59] identifies the problems of online courses with screen readers and recommends solutions with the effective use of metadata for a better understanding of the course material. Vizoso [46] refers to the ESVIAL Project Guide as a model of transformation and proposal of good practices in accessibility, based on the participation and collaborative construction of adapted educational resources and the needs of the student. Batanero et al. [30, 52] propose the implementation of an adaptation in the Moodle platform. The participants were 10 blind, 10 deaf and 3 deaf-blind students whose age ranged between 26 and 50 years. The study describes adaptations to students in Moodle based on their preferences and the incorporation of accessible resources with the possibility of reuse. Besides, the authors emphasize that audio descriptions of the secondary elements should be carefully limited to avoid problems with other disabilities. Sanchez-Gordon and Luján-Mora [64] established the need for further research in the specification of online and off-line accessibility requirements. As an example, the authors described specific cases of Chemistry learning requirements, their experimentation, reports, and discussion forums. In response to RQ3, it can be said that there is empirical evidence related to the impact of metadata on the preferences and needs of students with disabilities. However, it is necessary to consider the continuous and active attention to the needs of functional diversity that may arise in the educational context. In this sense, the implementation of accessibility metadata would be a fundamental contribution to the generation of repositories, as well as its constant feedback on the experience of the student with disabilities and the various scenarios that exist in the educational process.

4.5 RQ4: What are the challenges and opportunities that have been addressed in this area of research?

In general, some research points out the lack of tools and systems in virtual learning environments for the application of accessibility metadata. In this topic, [36] established the lack of reviews related to the issue of accessibility by the different educational platforms. However, it is worth noting the existence of literature on the analysis of limited scope on some courses. Batanero et al. [33] recommended

the application of standards based on the general analysis of web accessibility and the level of compliance with the WCAG standard. The understanding of the different standards in the area of accessibility and adaptability leads to future studies focused on developing evaluation mechanisms, automatic tools, and methodological proposals in order to contribute to the development of accessibility in e-learning. It is important to measure the impact on the user experience [55] considering the use of assistive technology [59]. Another great challenge is to provide students with advanced and personalized services to efficiently manage and disseminate educational material [65]. The difficulty of effectively interpreting the content of educational resources that facilitates personalization constitutes a research challenge. Lin et al. [62]. It is worth building systems with intuitive adaptations that facilitate the delivery and selection of educational resources for students with disabilities [30, 46]. In addition, the generation of instructional design methodologies is important because it supports the management and dissemination of educational material according to specific needs [58]. The development of tools that strengthen the applicability of accessibility metadata is also required. There exist frameworks based on semantic rules that facilitate the self-personalization of assistive technologies [48]. However, other mechanisms are necessary for the recommendation of learning objects, e.g., self-organization strategies [56] and self-control [61]. Recommender systems are also needed to refine the modeling of user profiles in order to establish accessibility requirements for courses and develop a holistic approach [47], or based on the learning profiles of other students with similar needs or preferences [66].

The establishment of good accessibility practices in a teaching-learning process is time consuming, since it is necessary to establish pre- and post-comparisons. Rodriguez-Ascaso et al. [50] present projects of 48 months to address the needs of Accessible Lifelong Learning, as the EU4ALL project that finally lasted 54 months. Additionally, the complexity to design adapted applications is determined due to the wide range of characteristics in the functional diversity of students and the lack of reliable specific data [31]. Considering that metadata come from multiple and heterogeneous sources, metadata are compiled with different approaches and used in different contexts [60]. However, the ability to discover resources that do not adjust to a common standard is difficult [37, 67]. Pal et al. [63] determines the need to establish a generic model that leads to the use of a universal ontology for all educational domains, which could categorize all the metadata of different topics and subjects. However, there is a lack of a methodological framework for the implementation of an accessible virtual educational project. Therefore, it is necessary to incorporate metrics based on accessibility indicators that facilitate the evaluation of the results obtained in the different phases [39]. The involvement of teachers in the use and creation of educational resources, their dynamic characteristics and organizational structures are also necessary [68]. The sustainability and scalability of an educational resource depend on the socialization of the optimal use of repositories and reuse of resources according to the needs of the teaching-learning process. The quality of a resource, including its metadata and accessibility information, represents a broad topic that needs to be integrated [32]. Although some parameters to measure quality are in competition with each other, both peer review tools and user evaluation tools are methods to evaluate the quality of resources. Thus, [69] suggests three dimensions of analysis: priority, possibility of achieving (responsibility) and sustainability. Although the use of HTML5 is expected to increase in some areas including education [53], the implementation of accessibility metadata in educational resources is still incipient. According to [64], a mapping with eight dimensions of research on the issue of accessibility and MOOCs is proposed, establishing important guidelines in future research. In addition, more research is needed on automatic procedures and policy measures to support and monitor learning activities that involve a massive number of students [12], also considering other areas of knowledge such as exact sciences and required adaptations [52]. Future search processes could be facilitated through metadata editors capable of interpreting and reading files generated by various tools [34]. For example, [57] presents a conceptual framework for the automated generation of metadata that highlights the importance of adaptive e-learning process based on the learning activity profile. It is also necessary to have automatic support tools that facilitate the use of accessibility metadata [49] in order to detect drawbacks and successes and propose alternatives in order to increase accessible educational resources in various repositories. In response to RQ4, it can be said that the field of accessibility is extensive, so the techniques and associated standards need to be homogenized and socialized to boost their use among e-learning resource developers. The use of metadata needs to be extended to accessible educational resources, in such a way that the learning curve can be reduced. Additionally, a common language in the development of accessible digital resources with easy implementation and search on the web should be developed.

4.6 Limitations

This systematic review presented some limitations during the process of answering the research questions. The selection of the research keywords and exclusion criteria may limit relevant searches, as may the language. The systematic review sought to identify a theoretical context, so it was based on databases of scientific literature. Gray literature is not included. The omission of articles may also respond

to the selected period time 2012–2019. The study was carried out since 2012 because big corporations as Google, Yahoo and Bing started to use schema.org in 2011. Since then, it called the attention of practitioners and researchers. Bias was reduced by choosing a set of databases that cover the main disciplinary fields in which accessibility and metadata can be addressed (computer science and education). To minimize bias, a systematic process was defined to perform the data extraction. In fact, an optimum level of reliability (86.1%) among researchers was determined by calculating a coefficient of krippendorff's alpha. Another limitation is the exclusion of documents written in another language (than English or Spanish) and having less than 4 pages, so it is possible that current research status in other countries is missing. Even so, the systematic review process is considered to offer a good overview of the metadata and accessibility research status, identifying the relationships between the evaluation of e-learning environments and accessibility metadata.

5 Discussion and recommendations

This systematic review aimed to provide an overview of the current state of research on accessibility metadata in virtual environments. The results show a lack of its use in educational resources and learning objects. The guidelines on the use of accessibility metadata respond to subjective criteria and depend on local or institutional models of evaluation. Some studies also show a lack of measurement of the impact on the applicability of metadata on the preferences and needs of students with disabilities, as well as a lack of satisfactory monitoring and evaluation of the teaching-learning process. In fact, studies report only a limited number of subjects in a specific period.

As a result of this review, the need to use and evaluate the accessibility and adaptability of learning objects and courses in e-learning through standards and metadata is identified.

Through the findings and research perspectives in the various solution proposals to improve the field of accessibility and adaptability in virtual environments, it is relevant to explore the efforts generated by establishing standards and regulations throughout history. Although [36, 47, 70] apply numerous practices to incorporate metadata of accessibility, it is still complex to respond to models of evaluation in e-learning that consider accessibility guidelines but that do not converge with metadata standards proposed for the effect. The advantages of adequate implementation of metadata are not yet widely known, as concluded by several authors [37, 64]. The trend of HTML5 could favor the correct adoption of effective accessibility metadata practices [53]. This would generate progress to find accessible educational resources according to the needs and preferences of the student. The efforts made to create accessible educational material could enrich the universality of education. Recommender tools [49, 61, 66] favor information on accessible educational resources and facilitate the identification of various student profiles. It is possible to compare the effectiveness and degree of satisfaction of a student through interaction with adequate resources. The needs and preferences of a student should be in accordance with resources that meet those requirements. The accessible educational material generated could favor repositories and enrich the educational process.

This SLR leads us to identify the impact of accessibility metadata in virtual environments. The primary studies reveal interest in improving the implementation of accessibility in educational resources. Therefore, the challenge is to build tools and develop techniques that foster proper accessibility metadata application and evaluation. LOM editors also facilitate the implementation and storage of metadata in resources, e.g., LOMPad, a freely distributed editor that is widely used. However, accessibility metadata are not considered in that editor yet. By reviewing the literature, one can conclude that there exists no accessibility evaluation model based on metadata. As future work, it is necessary to generate new metadata that allow to comply to the guidelines proposed by WCAG 2.1. The implementation of the different standards in accessible educational resources must be validated, and determine which is the best. The implementation of tools that facilitate the adequate incorporation of accessibility metadata is required. Accessibility in virtual education is a subject that must be disseminated, so it is urgent to contribute with educational material according to the functional diversity of learning. There is no mythical "regular student" so it is necessary to provide multiple forms of interaction and representation.

6 Conclusion

The objective of our SLR was to determine the state of the art of accessibility metadata in e-learning environments, in particular digital educational resources. This review is part of an ongoing research project. Despite the major limitations of this study, limited academic literature and limited period of time, we believe that the present SLR gives a good overview of this topic. Bias was reduced by following a protocol based on a rigorous methodology. In fact, an optimal reliability was reached when level of agreement among the reviewers was calculated. The findings reveal little research in this topic. Although, only 31 primary studies were found, we can draw three main conclusions based on the research questions. First, there is a shortage of applicability of accessibility metadata in resources and virtual educational repositories. In addition, previous studies tend to

focus more on providing recommendations than on assessing the effectiveness of their implementation with students with disabilities. Secondly, the use of accessibility standards and metadata is subjective. In several cases, evaluation models consider accessibility as an evaluative metric, but there is not a common implementation process. Third, there is a lack of empirical evidence. In fact, the reliability of the results is threatened due to the relatively small sample size of students with disabilities, as well as the short period of time to track and monitor students' learning process. However, reviewing the literature allowed to identify some research gaps.

In summary, this study identifies the different specifications, standards, and tools that include accessibility metadata. It seeks to highlight relevant regulations created by IMS[1] and its great contribution by being considered as an ISO standard and currently accepted by schema.org[2]. These findings can help other researchers and developers to better understand the role of accessibility metadata in modeling virtual educational resources considering the needs and preferences of the learner. The integration of accessibility metadata in educational resources and learning objects has a great influence on the effective response of personalized search engines according to the interaction requirements of an educational resource. Finally, this study reveals that although previous contributions have originated standards and specifications that motivated relevant investigation, there is a lack of proper implementation and frequent use of accessibility metadata. Most research works identify limitations in the standardization of metadata applicability; therefore, it is a big challenge. The results of quantitative, qualitative and mixed studies are insufficient to determine the impact on students with disabilities, so there is not enough empirical evidence (inconclusive data) regarding applicability in educational resources and search repositories.

Appendix 1: Data extracted

See Table 4.

Table 4 References of all primary studies founded in this SLR [71]

Study ID	Title	Type of publication	Reference	Citation Google 30/08/2020
S01	Accessibility and MOOC: Toward a holistic perspective	Journal	[36]	7
S02	Accessible platforms for e-learning: A case study	Journal	[30]	6
S03	A Learning Quality Metadata approach: Automatic quality assessment of virtual training from metadata	Journal	[32]	3
S04	A proposal based on knowledge modeling and ontologies to support the accessibility evaluation process of learning objects	Conference	[49]	-
S05	A preliminary study for developing accessible MOOC services	Journal	[47]	15
S06	A method to evaluate accessibility in e-learning education systems	Conference	[33]	17
S07	Accessible lifelong learning at higher education: Outcomes and lessons learned at two different pilot sites in the EU4ALL project	Journal	[5]	45
S08	An integrated semantic framework supporting universal accessibility to ICT	Journal	[48]	10
S09	An e-learning recommendation approach based on the self-organization of learning resource	Journal	[56]	48
S10	Bridging the accessibility gap in Open Educational Resources	Journal	[55]	18
S11	Characterization of Educational Resources in e-Learning Systems Using an Educational Metadata Profile	Journal	[58]	23
S12	Considering student personal needs and preferences and accessible learning objects to adapt moodle learning platform	Conference Paper	[51]	5
S13	Creating a LO Metadata Profile for Distance Learning: An Ontological Approach	Conference	[65]	10
S14	Dealing with metadata quality: The legacy of digital library efforts	Journal	[60]	42
S15	Description of accessible learning resources by using metadata	Conference Paper	[34]	1
S16	Designing online courses for screen reader users	Journal	[59]	2

[1] https://www.imsglobal.org/activity/accessibility.

[2] https://schema.org/.

Table 4 (continued)

Study ID	Title	Type of publication	Reference	Citation Google 30/08/2020
S17	Formalización de un marco metodológico para la implementación de un proyecto educativo virtual accesible	Journal	[29]	11
S18	Metadatos de accesibilidad en recursos educativos: análisis y propuesta	Journal	[46]	2
S19	Microdata with Schema vocabulary: Improvement search results visualization of open educational resources	Conference	[37]	3
S20	Personalized Educational Paths Through Self-Modifying Learning Objects	Conference	[57]	2
S21	PLORS: a personalized learning object recommender system	Journal	[66]	66
S22	Questions of quality in repositories of open educational resources: a literature review	Journal	[66]	64
S23	Research challenges in accessible MOOCs: a systematic literature review 2008-2016	Journal	[64]	41
S24	Setting accessibility preferences about learning objects within adaptive elearning systems: User experience and organizational aspects	Journal	[12]	11
S25	Through efficient use of LORs: Prospective teachers' views on operational aspects of learning object repositories	Journal	[68]	10
S26	Toward a holistic model for quality of learning object repositories: A practical application to the indicator of metadata compliance	Journal	[72]	2
S27	User-centred design and educational data mining support during the recommendations elicitation process in social online learning environments	Journal	[61]	40
S28	A Quantitative Analysis of the Use of Microdata for Semantic Annotations on Educational Resources	Journal	[53]	4
S29	Effects of New Supportive Technologies for Blind and Deaf Engineering Students in Online Learning	Journal	[52]	3
S30	A semi-automatic metadata extraction model and method for video-based e-learning contents	Journal	[63]	2
S31	From ideal to reality: segmentation, annotation, and recommendation, the vital trajectory of intelligent micro learning	Journal	[62]	4

Appendix 2: Quality assessment checklist

See Table 5.

Table 5 Assessment criteria and description of checklist

Item	Assessment Criteria	Description of checklist
QA1	Does the data collection respond to well-structured procedures?	Yes. The data collection procedures are well structured. No. The procedures for data collection are not described. Partially. Data is presented but does not specify its collection procedure
QA2	Is the research methodology clearly identified?	Yes. The methodology of the investigation is clearly identified. No. The methodology of the investigation is not clearly identified. Partially. A description of the proposed approach is presented
QA3	Are the study participants or the observation units adequately described?	Yes. Study participants or observation units are adequately described. No. Absence the description of participants or observation units. Partially. It indicates the existence of participants or functional units but not with a case study or sample establishment.In several cases reference is made to previous studies
QA4	Were the results of the study clearly established?	Yes. The results are clearly established. No. The results are not established. Partially. The results are presented but not clearly established
QA5	Are the approach and the formulation of conclusions and future work well transmitted?	Yes. The approach and the formulation of conclusions and future work are well transmitted. No. Approach and formulation of conclusions and future work are not identified. Partially. Future work or conclusions are not well transmitted

Acknowledgements This deliverable has been co-funded by the Erasmus+ Programmer of the European Union, project EduTech (609785-EPP-1-2019-1-ES-EPPKA2-CBHE-JP). The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Funding Open Access funding provided thanks to the CRUE-CSIC agreement with Springer Nature.

References

1. Denise, C., Shannon, J.: Quality assurance and accreditation in higher education. In: Insung, J. (ed.) 711 Third Avenue. Taylor & Francis, New York (2012)
2. Jung, I., Li, C., Meng Wong, T., Belawati, T., Zuhairi, A., Fuduka, A.: Nationan Quality Assurance Systems in Distance Education in Asia (2017)
3. Ossiannilsson, E., Williams, K., Camilleri, A. F., Brown, M.: Quality models in online and open education around the globe. State of the art and recommendations, DISTANCE Educ., p. 55 (2015)
4. Temesio, S., Motz, R.: Ecosistema de Accesibilidad en entornos virtuales, PhD Thesis (2015)
5. Segovia, C. F.: Accesibilidad e Internet. Argentina (2007)
6. World Bank Group: Discapacidad: Panorama General, vol. 2016 (2015)
7. ONU: The Secretariat for the Convention on the Rights of Persons with Disabilities (SCRPD), vol. 2016 (2006)
8. Incheon Declaration, vol. 2017 (2015)
9. ESVI-AL: Guía Metodológica y Modelo de Acreditación ESVI-AL (2009). http://www.esvial.org/guia/. Accessed 05 May 2019
10. ISO/IEC 25000: ISO/IEC 25000:2014, ISO (2014). http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/47/64764.html. Accessed 18 Dec 2019
11. ISO/IEC 24751-2: ISO/IEC 24751-2. ISO (2008). http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/04/36/43603.html. Accessed 14 Feb 2019
12. Rodriguez-Ascaso, A., Boticario, J.G., Finat, C., Petrie, H.: Setting accessibility preferences about learning objects within adaptive elearning systems: user experience and organizational aspects. Expert Syst. **34**(4), e12187 (2017). https://doi.org/10.1111/exsy.12187
13. Camilleri, A.F., Ehlers, U., Pawlowski, J.M.: State of the Art Review of Quality Issues related to Open Educational Resources (OER) (2014). https://doi.org/10.2791/80171
14. Molenda, M.: In search of the elusive ADDIE model. Perform. Improv. **42**(5), 34–36 (2003). https://doi.org/10.1002/pfi.4930420508
15. Ipek, D.I., Sözcü, D.Ö.F.: Considerations for task analysis methods and rapid e-learning development techniques. Asia Pac. J. Multidiscip. Res. **2**(1), 20–24 (2014)
16. Mejía, J. F., López, D.: Modelo de Calidad de E-learning para Instituciones de Educación Superior en Colombia, Form. Univ., vol. 9, no. 2 (2016). http://www.redalyc.org/resumen.oa?id=373544971007. Accessed 10 Feb 2019
17. Serie Informes CNICE: Centro Nacional de Información y Comunicación Educativa (CNICE-MEC) (2004). http://ares.cnice.mec.es/informes/11/contenido/44.htm#5. Accessed 20 Feb 2019
18. ACDE: The African Council for Distance Education (ACDE). The African Council for Distance Education (ACDE) (2004). http://www.acde-afri.org/qa/. Accessed 04 May 2019
19. AVU: ODeL and Inclusivity: Enhancing Learning Opportunities for Persons with Disabilities in Africa. Feb. (2018). [Online]. https://oer.avu.org/handle/123456789/688. Accessed 05 May 2019
20. AENOR: UNE 66181:2012, AENOR, Jul. (2012). https://www.aenor.com/normas-y-libros/buscador-de-normas/une/?c=N0049661. Accessed 05 May 2019
21. ISO 9241-11: ISO 9241-11:2018, 2018. https://www.iso.org/standard/63500.html. Accessed 31 July 2018
22. ISO/IEC 19778-3: ISO/IEC 19778-3:2015—Information technology—Learning, education and training—Collaborative technology—Collaborative workplace—Part 3: Collaborative group data model, ISO, 2015. http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/06/50/65099.html. Accessed 14 Feb 2019
23. ISO/IEC 19796-3: ISO/IEC 19796-3:2009—Information technology—Learning, education and training—Quality management, assurance and metrics—Part 3: Reference methods and metrics, ISO, 2009. http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/04/61/46159.html. Accessed 14 Feb 2019
24. ISO/IEC 24751-3: ISO/IEC 24751-3:2008—Information technology—Individualized adaptability and accessibility in e-learning, education and training—Part 3: 'Access for all' digital resource description, ISO, 2008. http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/04/36/43604.html. Accessed 14 Feb 2019
25. ISO/IEC 40500: ISO/IEC 40500:2012—Information technology—W3C Web Content Accessibility Guidelines (WCAG) 2.0, ISO (2012). http://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/86/58625.html. Accessed 14 Feb 2019
26. Otón Tortosa, S., et al.: Evolution of accessibility metadata in educational resources. Httpservicesigi-Glob.-1-7998-2325-4ch001, vol. UXD and UCD Approaches for Accessible Education, Jan (2020). https://doi.org/10.4018/978-1-7998-2325-4.ch001
27. W3C: WebSchemas/Accessibility, W3C, Mar. 23 (2017). https://www.w3.org/wiki/WebSchemas/Accessibility. Accessed 07 Sep 2019
28. IMS Global Learning Consortium: Accessibility|IMS Global Learning Consortium (2012). http://www.imsglobal.org/activity/accessibility. Accessed 10 Feb 2019
29. Amado-Salvatierra, H.R., Gonzólez, J.H., Tortosa, S.O.: FormalizaciÓn de un marco metodolÓgico para la implementaciÓn de un proyecto educativo virtual accesible. Educ. XX1 21(2) (2018). https://doi.org/10.5944/educxx1.15591
30. Batanero, C., et al.: Accessible platforms for e-learning: a case study. Comput. Appl. Eng. Educ. **25**(6), 1018–1037 (2017). https://doi.org/10.1002/cae.21852
31. Temesio Vizoso, S.G.: Metadatos de accesibilidad en recursos educativos: análisis y propuesta. Palabra Clave 7(1) (2017). https://doi.org/10.24215/18539912e040
32. Pons, D., Hilera, J.R., Fernández, L., Pagés, C.: A learning quality metadata approach: automatic quality assessment of virtual training from metadata. Comput. Stand. Interfaces **45**, 45–61 (2016). https://doi.org/10.1016/j.csi.2015.12.001

33. Batanero, C., Karhu, M., Holvikivi, J., Otón, S., Amado-Salvatierra, H.R.: A method to evaluate accessibility in e-learning education systems. In: 2014 IEEE 14th International Conference on Advanced Learning Technologies, pp. 556–560 (2014). https://doi.org/10.1109/ICALT.2014.163
34. Otón, S., Batanero, C., García, E., García-Cabot, A., Barchino, R.: Description of accessible learning resources by using metadata (2014). https://doi.org/10.5220/0004895606200626
35. Fidalgo, Á., Sein-Echaluce, M. L.: Teaching Innova Project: The Incorporation of Adaptable Outcomes in Order to Grade Training Adaptability, p. 22 (2013)
36. Rodriguez-Ascaso, A., González Boticario, J.: Accesibilidad y MOOC: Hacia una perspectiva integral. RIED Rev. Iberoam. Educ. Distancia 18, no. 2, May (2015). https://doi.org/10.5944/ried.18.2.13670
37. Navarrete, R., Lujan-Mora, S.: Microdata with schema vocabulary: improvement search results visualization of open educational resources. In: 2018 13th Iberian Conference on Information Systems and Technologies (CISTI), Jun (2018), pp. 1–6. https://doi.org/10.23919/CISTI.2018.8399222
38. Brereton, P., Kitchenham, B.A., Budgen, D., Turner, M., Khalil, M.: Lessons from applying the systematic literature review process within the software engineering domain. J. Syst. Softw. **80**(4), 571–583 (2007). https://doi.org/10.1016/j.jss.2006.07.009
39. Liberati, A., et al.: The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. PLOS Med. **6**(7), E1000100 (2009). https://doi.org/10.1371/journal.pmed.1000100
40. Vieira, C., Parsons, P., Byrd, V.: Visual learning analytics of educational data: a systematic literature review and research agenda. Comput. Educ. **122**, 119–135 (2018). https://doi.org/10.1016/j.compedu.2018.03.018
41. Kitchenham, B.: Guidelines for performing Systematic Literature Reviews in Software Engineering, p. 44 (2007)
42. Krippendorff, K.: Computing Krippendorff's Alpha-Reliability, p. 12, Jan (2011)
43. Cinquin, P.-A., Guitton, P., Sauzéon, H.: Online e-learning and cognitive disabilities: a systematic review. Comput. Educ. **130**, 152–167 (2019). https://doi.org/10.1016/j.compedu.2018.12.004
44. Sánchez-Gordón, M., Colomo-Palacios, R.: Taking the emotional pulse of software engineering: a systematic literature review of empirical studies. Inf. Softw. Technol. **115**, 23–43 (2019). https://doi.org/10.1016/j.infsof.2019.08.002
45. Wieringa, R.J., Maiden, N., Mead, N., Rolland, C.: Requirements engineering paper classification and evaluation criteria: a proposal and a discussion. Requir. Eng. **11**(1), 102–107 (2006). https://doi.org/10.1007/s00766-005-0021-6
46. Vizoso, S.G.T.: Metadatos de accesibilidad en recursos educativos: análisis y propuesta. Palabra Clave 7(1) (2017). https://doi.org/10.24215/18539912e040
47. Iniesto, F., Rodrigo, C.: A preliminary study for developing accessible D services. J. Access. Des. All **6**(2), 125–149 (2016). https://doi.org/10.17411/jacces.v6i2.117
48. Koutkias, V., Kaklanis, N., Votis, K., Tzovaras, D., Maglaveras, N.: An integrated semantic framework supporting universal accessibility to ICT. Univers. Access Inf. Soc. Heidelb. **15**(1), 49–62 (2016). https://doi.org/10.1007/s10209-014-0372-1
49. Ingavélez-Guerra, P., et al.: A proposal based on knowledge modeling and ontologies to support the accessibility evaluation process of learning objects. In: 2018 Congreso Argentino de Ciencias de la Informática y Desarrollos de Investigación (CACIDI), Nov , pp. 1–5 (2018). https://doi.org/10.1109/CACIDI.2018.8584355
50. Rodriguez-Ascaso et al.: Accessible lifelong learning at higher education: outcomes and lessons learned at two different pilot sites in the EU4ALL project. JUCS J. Univers. Comput. Sci. 18(1) (2012). https://doi.org/10.3217/jucs-018-01-0062
51. Batanero, C., Otón, S., Holvikivi, J.: Considering student personal needs and preferences and accessible learning objects to adapt Moodle learning platform. In: 23RD International Conference on Information Systems Development ISD2014 CroatIA, p. 8 (2014)
52. Batanero, C., de-Marcos, L., Holvikivi, J., Hilera, J. R., Otón, S.: Effects of new supportive technologies for blind and deaf engineering students in online learning. IEEE Trans. Educ. **62**(4), 270–277 (2019). https://doi.org/10.1109/TE.2019.2899545
53. Navarrete, R., Luján-Mora, S.: A Quantitative Analysis of the Use of Microdata for Semantic Annotations on Educational Resources (2018). [Online]. http://rua.ua.es/dspace/handle/10045/73711. Accessed 19 Apr 2019
54. Schema: CreativeWork—schema.org Type (2011). http://schema.org/CreativeWork. Accessed 23 Dec 2019
55. Navarrete, R., Luján-Mora, S.: Bridging the accessibility gap in open educational resources. Univers. Access Inf. Soc. **17**(4), 755–774 (2018). https://doi.org/10.1007/s10209-017-0529-9
56. Wan, S., Niu, Z.: An e-learning recommendation approach based on the self-organization of learning resource. Knowl. Based Syst. **160**, 71–87 (2018). https://doi.org/10.1016/j.knosys.2018.06.014
57. Pashev, G., Totkov, G., Kostadinova, H., Indzhov, H.: Personalized educational paths through self-modifying learning objects. In: Proceedings of the 17th International Conference on Computer Systems and Technologies 2016—CompSysTech'16, Palermo, Italy, pp 437–444 (2016). https://doi.org/10.1145/2983468.2983516
58. Solomou, G., Pierrakeas, C., Kameas, A.: Characterization of educational resources in e-learning systems using an educational metadata profile. J. Educ. Technol. Soc. Palmerst. North **18**(4), 246–260 (2015)
59. Kearns, L.R., Frey, B.A., McMorland, G.: Designing online courses for screen reader users. J. Asynchronous Learn. Netw. **17**(3), 73–86 (2013)
60. Tani, A., Candela, L., Castelli, D.: Dealing with metadata quality: the legacy of digital library efforts. Inf. Process. Manag. **49**(6), 1194–1205 (2013). https://doi.org/10.1016/j.ipm.2013.05.003
61. Santos, O.C., Boticario, J.G.: User-centred design and educational data mining support during the recommendations elicitation process in social online learning environments. Expert Syst. **32**(2), 293–311 (2015). https://doi.org/10.1111/exsy.12041
62. Lin, J., et al.: From ideal to reality: segmentation, annotation, and recommendation, the vital trajectory of intelligent micro learning. World Wide Web **23**(3), 1747–1767 (2020). https://doi.org/10.1007/s11280-019-00730-9
63. Pal, S., Pramanik, P.K.D., Majumdar, T., Choudhury, P.: A semi-automatic metadata extraction model and method for video-based e-learning contents. Educ. Inf. Technol. **24**(6), 3243–3268 (2019). https://doi.org/10.1007/s10639-019-09926-y
64. Sanchez-Gordon, S., Luján-Mora, S.: Research challenges in accessible MOOCs: a systematic literature review 2008–2016. Univers. Access Inf. Soc. **17**(4), 775–789 (2018). https://doi.org/10.1007/s10209-017-0531-2
65. Nikolopoulos, G., Kalou, A., Pierrakeas, C., Kameas, A.: Creating a LO metadata profile for distance learning: an ontological approach. In: Dodero, J.M., Palomo-Duarte, M., Karampiperis, P. (eds.) Metadata and Semantics Research, vol. 343, pp. 37–48. Springer, Berlin (2012)
66. Imran, H., Belghis-Zadeh, M., Chang, T.-W., Kinshuk, G.S.: PLORS: a personalized learning object recommender system. Vietnam J. Comput. Sci. **3**(1), 3–13 (2016). https://doi.org/10.1007/s40595-015-0049-6
67. Dias, S.B., Diniz, J.A.: Towards an enhanced learning management system for blended learning in higher education incorporating distinct learners? Profiles. J. Educ. Technol. Soc. Palmerst. North **17**(1), 307–319 (2014)

68. Yalcinalp, S., Emiroglu, B.: Through efficient use of LORs: prospective teachers' views on operational aspects of learning object repositories. Br. J. Educ. Technol. **43**(3), 474–488 (2012). https://doi.org/10.1111/j.1467-8535.2011.01212.x
69. Atenas, J., Havemann, L.: Questions of quality in repositories of open educational resources: a literature review. Res. Learn. Technol. Jarfalla (2014). https://doi.org/10.3402/rlt.v22.20889
70. Rodríguez, G., Pérez, J., Cueva, S., Torres, R.: A framework for improving web accessibility and usability of Open Course Ware sites. Comput. Educ. **109**, 197–215 (2017). https://doi.org/10.1016/j.compedu.2017.02.013
71. Ingavelez-Guerra, P.C.: Systematic Literature Review Analysis (2019). https://doi.org/10.6084/m9.figshare.11441523.v1
72. Vidal-Castro, C., Segura Navarrete, A.A., Menendez-Dominguez, V., Martinez-Araneda, C.: Towards a holistic model for quality of learning object repositories: a practical application to the indicator of metadata compliance. Electron. Libr. **35**(5), 953–976 (2017). https://doi.org/10.1108/EL-10-2015-0202