Universidad de Alcalá

Doctorado en Ingeniería de la Información y del Conocimiento

Evaluación de la Accesibilidad y Adaptabilidad de Objetos de Aprendizaje y cursos online a través de estándares y metadatos

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Resumen

A través de los hallazgos, perspectivas de investigación y los desafíos planteados para mejorar el campo de la accesibilidad en la creación, gestión y evaluación de Objetos de aprendizaje (OAs), resulta relevante explorar los esfuerzos generados por establecer modelos que fomenten la accesibilidad. Las propuestas para transversalizar la accesibilidad en la educación virtual aún resulta complejo aplicarlas, sin embargo se identifica modelos, estándares y buenas prácticas que buscan aportar en el proceso educativo virtual y el diseño del aprendizaje para todos. Las ventajas de una adecuada implementación de la accesibilidad y adaptabilidad en OAs aún no es un conocimiento de dominio general. La presente investigación presenta una propuesta de solución enfocada en la correcta publicación de información de accesibilidad mediante metadatos, para favorecer la adopción de prácticas que generen una dirección futura que pueda centrarse en la efectiva búsqueda de recursos educativos que respondan a la necesidades y preferencias de un estudiante con discapacidad, considerando que los esfuerzos generados por crear material educativo accesible, enriquece la universalidad de la educación. La creación, gestión y evaluación de OAs accesibles, logran sincronía con recursos que pueden ser reutilizados. El análisis de casos de estudio nos ubica en el impacto de evaluar OAs accesibles a través de metadatos. Los hallazgos analizados manifiestan la potencialidad de su implementación. Se establece una necesidad importante en la generación de herramientas y técnicas que promuevan su desarrollo y fortalezcan su evaluación e impacto. Se considera que es necesario establecer directrices de accesibilidad que guíen en la eliminación de barreras, por lo que es necesario mantener una exploración e investigación activa de las fortalezas y debilidades de los recursos educativos accesibles, compatibilidad con tecnología de asistencia y la implementación y socialización de herramientas que favorezcan las capacidades de evaluación de OAs accesibles para generar una cultura de diseño inclusivo lo cual contribuye a una óptima evaluación de calidad . Se requiere de mayor investigación en las necesidades no solo de determinadas discapacidades, sino en el contexto de la

experiencia del aprendizaje, competencias digitales, diseño de plataformas, mantenimiento e inclusión de nuevas características.

Abstract

Through the findings, research perspectives and the challenges posed to improve the field of accessibility in the creation, management and evaluation of Learning Objects (LOs), it is relevant to explore the efforts generated by establishing models that promote accessibility. The proposals to mainstream accessibility in virtual education are still complex to apply, however, models, standards and good practices are identified that seek to contribute to the virtual educational process and the design of learning for all. The advantages of a proper implementation of accessibility and adaptability in LOs is not yet a general domain knowledge. This research presents a solution proposal focused on the correct publication of accessibility information through metadata. It seeks to promote the adoption of practices that generate a future direction that can focus on the effective search for educational resources that respond to the needs and preferences of a student with a disability. It is considered that the efforts generated by creating accessible educational material enriches the universality of education. The creation, management and evaluation of accessible LOs achieve synchronization with resources that can be reused. The analysis of case studies places us in the impact of evaluating LOs accessible through metadata. The analyzed findings show the potentiality of its implementation. An important need is established in the generation of tools and techniques that promote their development and strengthen their evaluation and impact. It is considered necessary to establish accessibility guidelines that guide the removal of barriers. It is necessary to maintain an active exploration and investigation of the strengths and weaknesses of accessible educational resources, compatibility with assistive technology. The implementation and socialization of tools that favor the evaluation capacities of accessible LOs. Generate a culture of inclusive design and with it an optimal quality assessment. More research is required on the needs not only of certain disabilities, but in the context of the learning experience, digital skills, platform design, maintenance and inclusion of new features.

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Capítulo 1. Introducción

1.1 Objetivo de la tesis

El principal objetivo de esta investigación es la elaboración de un modelo de evaluación de la accesibilidad y adaptabilidad de objetos de aprendizaje en ambientes virtuales utilizando metadatos, para lo cual se plantea los siguientes objetivos específicos:

- Realizar una revisión sistemática de la literatura (SLR) relacionada con el campo de estudio (accesibilidad, adaptabilidad, metadatos, evaluación de e-learning).
- Estudiar investigaciones precedentes sobre estándares, metadatos aplicados al e-learning y modelos de evaluación.
- Descubrir las líneas de investigación actuales del área en cuestión.
- Seleccionar estándares de accesibilidad de los objetos de aprendizaje a partir de los metadatos para establecer métricas.
- Proponer un modelo de evaluación de accesibilidad y adaptabilidad de objetos de aprendizaje basado en metadatos.
- Evaluar la propuesta mediante la generación de una herramienta automática que valide el modelo de evaluación de accesibilidad.
- Determinar casos de estudio que validen el modelo propuesto.

Por tanto, la hipótesis que plantea la presente tesis es la siguiente:

Es posible automatizar el proceso de evaluación de la accesibilidad y adaptabilidad de objetos de aprendizaje en ambientes virtuales utilizando un modelo basado en metadatos.

1.2 Motivación

En el tema de educación y discapacidad varios han sido los avances alcanzados, pero aún es difícil evaluar la acertada aplicación de ambientes virtuales accesibles. En muchos casos se particulariza o adapta el entorno virtual a una discapacidad específica, generando nuevas barreras de accesibilidad para otras(Castro et al., 2014), entendiendo por accesibilidad la propiedad que presentan los productos y servicios para poder ser utilizados por cualquier persona, incluidas aquellas con discapacidad. Paralelamente la adaptabilidad busca atender la diversidad propia del ser humano de tal manera que permita acomodarse a las necesidades de cada usuario y sus preferencias. La evaluación de un proceso, entorno o método, demanda constantemente la búsqueda de investigaciones actualizadas que vayan acorde a una realidad cambiante. En este sentido, la accesibilidad es un tema

extenso que requiere ser visto de manera transversal en varias áreas; educativas, sociales, culturales, entre otras (Temesio, 2016). Su relación con la adaptabilidad, discapacidad e inclusión es justificada desde varias razones, entre ellas tenemos: éticas (pensar más allá de uno mismo), sociales (llegar a un público más amplio contribuyendo a la diversidad), políticas (ser participantes activos de la gestión), económicas (perder clientes potenciales), en fin, todas aquellas que son vistas superficialmente por profesionales en fases de desarrollo e implementación (Segovia, 2007). En el tema de discapacidad es importante considerar las cifras a nivel mundial y su tendencia, pues alrededor de 1000 millones de habitantes, o el 15 % de la población mundial, tienen algún tipo de discapacidad, y su incidencia es mayor en países en desarrollo (BIRF-AIF, 2021) lo que constituye una tendencia poco alentadora, y más aun considerando la población que ingresa a tercera edad y su potencialidad de capacitación, lo que nos hace reflexionar sobre la necesidad de contar con procesos de evaluación que favorezcan la inclusión.

Basándose en el estudio doctoral de (Pons et al., 2016), se ha decidido profundizar en el tema de medición de accesibilidad a través de metadatos en ambientes virtuales, estudio que servirá para evaluar diversos modelos existentes acorde a sus parámetros asociados a la accesibilidad y relacionados.

Con el presente trabajo se busca aportar en procesos evaluativos de la accesibilidad de objetos de aprendizaje dentro de ambientes virtuales o cursos online, contemplando elementos necesarios a través de metadatos que se orienten a parámetros preexistentes, lo que conlleva a completar varias acciones investigativas en el planteamiento y evaluación de metadatos que contribuirán en estándares y mejoras de objetos de aprendizaje.

1.3 Preguntas de investigación

Las preguntas de investigación a las que trata de dar respuesta esta tesis doctoral son las siguientes:

RQ1: ¿Se emplean metadatos de accesibilidad en estándares y especificaciones sobre e-learning?

RQ2: ¿Es posible evaluar la accesibilidad y adaptabilidad en e-learning por la información contenida en metadatos?

RQ3: ¿Podrían los metadatos de accesibilidad impactar positivamente en las preferencias y necesidades de un estudiante con discapacidad?

RQ4: ¿Cómo se crean y gestionan recursos de aprendizaje accesibles a través de metadatos?

RQ5: ¿Es posible establecer métricas acordes a metadatos de accesibilidad y adaptabilidad para evaluar un objeto de aprendizaje?

RQ6: ¿Es necesario proponer nuevos metadatos de accesibilidad y adaptabilidad para evaluar un objeto de aprendizaje acorde a uno o más modelos?

RQ7: ¿Cuáles son los desafíos y oportunidades que se presentan esta área de investigación?

1.4 Tesis doctoral por compendio

El programa de Doctorado de Ingeniería de la Información y del Conocimiento, considera la posibilidad de realizar tesis doctoral por compendio de mínimo tres artículos de investigación , reconocidos en revistas de prestigio, argumentando la coherencia de la investigación y línea argumental del trabajo doctoral (Universidad de Alcalá, 2011).

La presente tesis doctoral presenta la selección de cuatro artículos que amparan la hipótesis y preguntas de investigación planteadas. Los artículos cumplen el requisito planteado en las guías de sexenios al ser publicaciones indexadas en JCR (Journal Citation Report):

- Use of Accessibility Metadata in e-Learning Environments: A Systematic Literature Review
- Accessibility Challenges in OER and MOOC: MLR Analysis Considering the Pandemic Years
- Automatic Adaptation of Open Educational Resources: An Approach From a Multilevel Methodology Based on Students' Preferences, Educational Special Needs, Artificial Intelligence and Accessibility Metadata
- RALO: Accessible Learning Objects Assessment Ecosystem based on metadata analysis, inter-rater agreement, and Borda voting schemes

1.5 Estructura del documento

- **Capítulo 1. Introducción**

  El capítulo 1 aborda la justificación de la investigación, sus objetivos y la descripción del proceso metodológico que lleva a cabo la tesis.

- **Capítulo 2. Compendio de artículos**

  Presenta los artículos considerados para la presentación de la tesis doctoral. Se incluye un resumen del artículo y el resultado del impacto.

- **Capítulo 3. Lista de artículos adicionales**

  El capítulo 3 presente el resultado de otras publicaciones, capítulos de libro participaciones en congresos y resultados de investigación.

- **Capítulo 4. Conclusiones y Futuras líneas de investigación.**

  En este capítulo se concluye el estudio con la identificación de desafíos y oportunidades en la gestión y evaluación de accesibilidad y adaptabilidad en objetos de aprendizaje para generar una cultura inclusiva y educación para todos.

Capítulo 2. Compendio de artículos

2 Compendio de artículos

Los objetivos planteados se han desarrollado amparados en una metodología de trabajo que considera:

- El Proceso exhaustivo de documentación y revisión bibliográfica, detecta las fuentes relacionadas con el tema a tratar que sean fiables y observar el estado actual del área de estudio (accesibilidad, metadatos, objetos de aprendizaje, e-learning). Con ello se considera el estudio de los recursos y realización de un análisis crítico a partir de los distintos resultados obtenidos y la redacción del estado del arte, donde se expongan ordenadamente los conocimientos adquiridos y se identifiquen los conceptos fundamentales (análisis de las modelos y estándares existentes y el nivel de accesibilidad que implementan). Son los artículos *"Use of Accessibility Metadata in e-Learning Environments: A Systematic Literature Review*" y "*Accessibility Challenges in OER and MOOC: MLR Analysis Considering the Pandemic Years"* los que respaldan este análisis
- La Creación de un modelo de evaluación de accesibilidad y adaptabilidad mediante el uso de metadatos de objetos de aprendizaje en cursos online, que responda a modelos y estándares evaluativos existentes con la propuesta de creación de una herramienta automática que a través de metadatos responda al modelo planteado. El artículo "*Automatic Adaptation of Open Educational Resources: An Approach From a Multilevel Methodology Based on Students' Preferences, Educational Special Needs, Artificial Intelligence and Accessibility Metadata"* responde a esta fase
- La ejecución de un proceso de análisis de la evaluación generada, la misma que permita validar o refutar la hipótesis de investigación propuesta, amparada en el análisis comparativo de datos obtenidos y clasificación de conclusiones extraídas mediante casos de estudio. El artículo "*RALO: Accessible Learning Objects Assessment Ecosystem based on metadata analysis, inter-rater agreement, and Borda voting schemes"* avala la investigación y hallazgos.

Con relación a los objetivos específicos y su correlación con los artículos seleccionados tenemos:

Tabla 1:Correlación objetivos con artículos presentados por compendio

Artículo	Obj. 1	Obj. 2	Obj. 3	Obj. 4	Obj. 5	Obj. 6	Obj. 7
Use of Accessibility Metadata in e-Learning Environments: A Systematic Literature Review	x	x	X				
Accessibility Challenges in OER and MOOC: MLR Analysis Considering the Pandemic Years.	x	x	X				
Automatic Adaptation of Open Educational Resources: An Approach From a Multilevel Methodology Based on Students' Preferences, Educational Special Needs, Artificial Intelligence and Accessibility Metadata				x	X		
RALO: Accessible Learning Objects Assessment Ecosystem based on metadata analysis, inter-rater agreement, and Borda voting schemes						X	X

2.1 Artículo I: Use of Accessibility Metadata in e-Learning Environments: A Systematic Literature Review

Presenta la revisión sistemática que platea la existencia de estudios que investigan el uso de metadatos de accesibilidad en ambientes e-learning. Este artículo tiene como objetivo presentar los resultados de una revisión sistemática centrada en los estándares de accesibilidad y adaptabilidad en e-learning a partir de sus metadatos, considerando criterios de inclusión y exclusión relevantes para este estudio.

2.1.1 Contribución

Se identifica las diferentes especificaciones, estándares y herramientas que incluyen metadatos de accesibilidad. Busca resaltar las normativas relevantes creadas por IMS y su gran aporte al ser considerado como estándar ISO y actualmente aceptado por schema.org . Estos hallazgos pueden ayudar a otros investigadores y desarrolladores a comprender mejor el papel de los metadatos de accesibilidad en el modelado de recursos

educativos virtuales teniendo en cuenta las necesidades y preferencias del alumno. La integración de metadatos de accesibilidad en recursos educativos y objetos de aprendizaje tiene una gran influencia en la respuesta efectiva de los buscadores personalizados de acuerdo con los requisitos de interacción de un recurso educativo. Finalmente, este estudio revela que si bien contribuciones anteriores han originado estándares y especificaciones que motivaron investigaciones relevantes, existe una falta de implementación adecuada y uso frecuente de metadatos de accesibilidad. La mayoría de las investigaciones encuentran limitaciones en la estandarización de la aplicabilidad de los metadatos, por lo que es un gran desafío. Los resultados de estudios cuantitativos, cualitativos y mixtos son insuficientes para determinar el impacto en los estudiantes con discapacidad, por lo que no existe suficiente evidencia empírica (datos no concluyentes) sobre la aplicabilidad en los recursos educativos y repositorios de búsqueda.

2.1.2 Artículo

Universal Access in the Information Society
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LONG PAPER

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

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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

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will ensure an inclusive education system at all levels as well as lifelong 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 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).

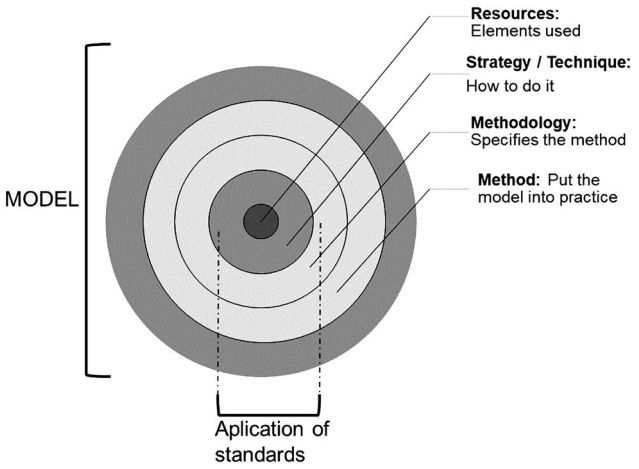

Fig. 1 Components of a model. This graph synthesizes in a layered way the different terms involved in a model and locates where standards are established

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

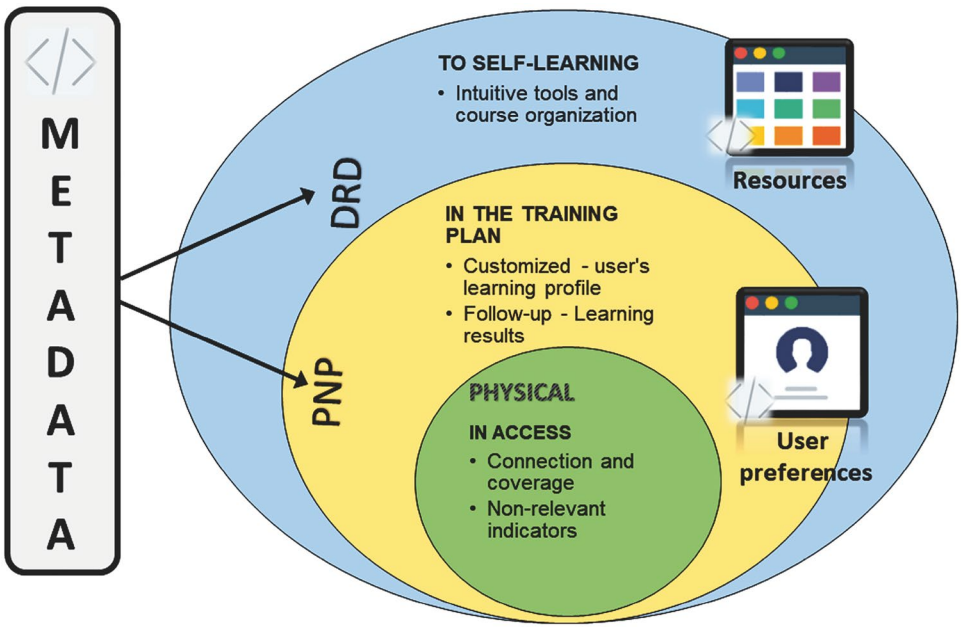

Fig. 2 Accessibility metadata. The graph presents the accessibility metadata components associated with resources and user requirements, considering ways of interaction

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.

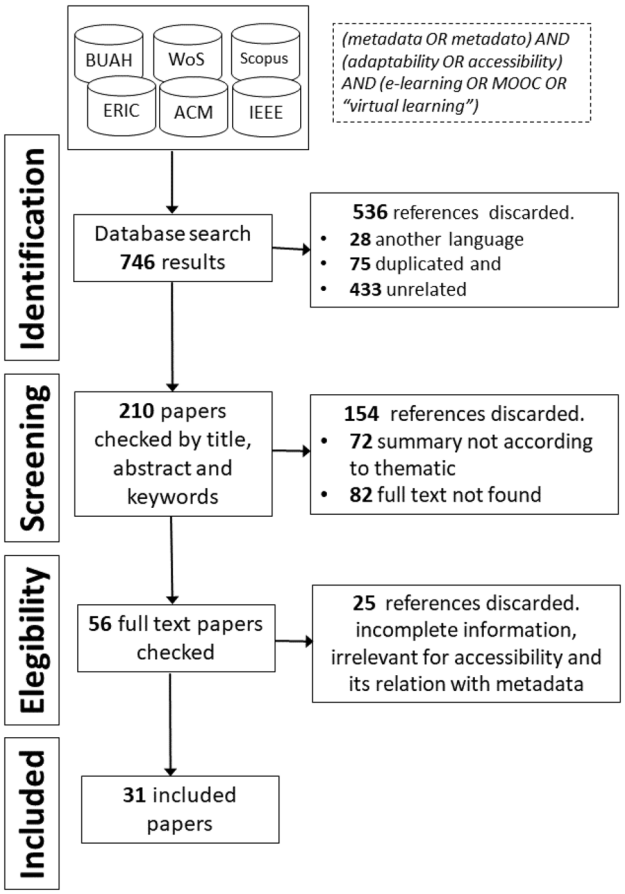

Fig. 3 Process of study selection criteria. The graph systematizes Kitchenham's [41] study scheme and the selection of criteria

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

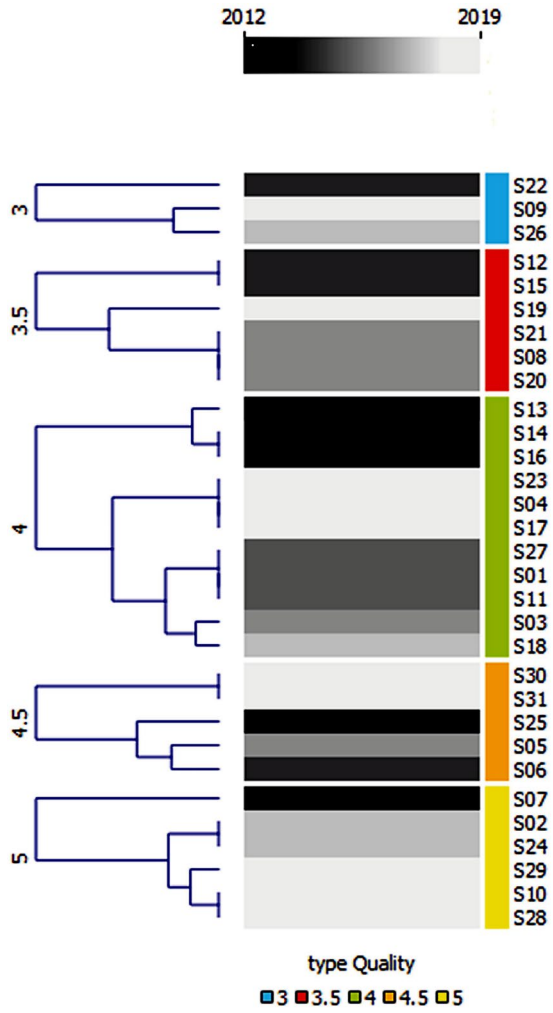

Fig. 4 Results of quality assessment. The heat map in gray tones shows the comparison of publications over the years and the quality evaluated. Studies published in 2012 are grayer as opposed to 2019 where the color tends to white. The numbers on the left of the figure show quality, the bars in the middle 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.

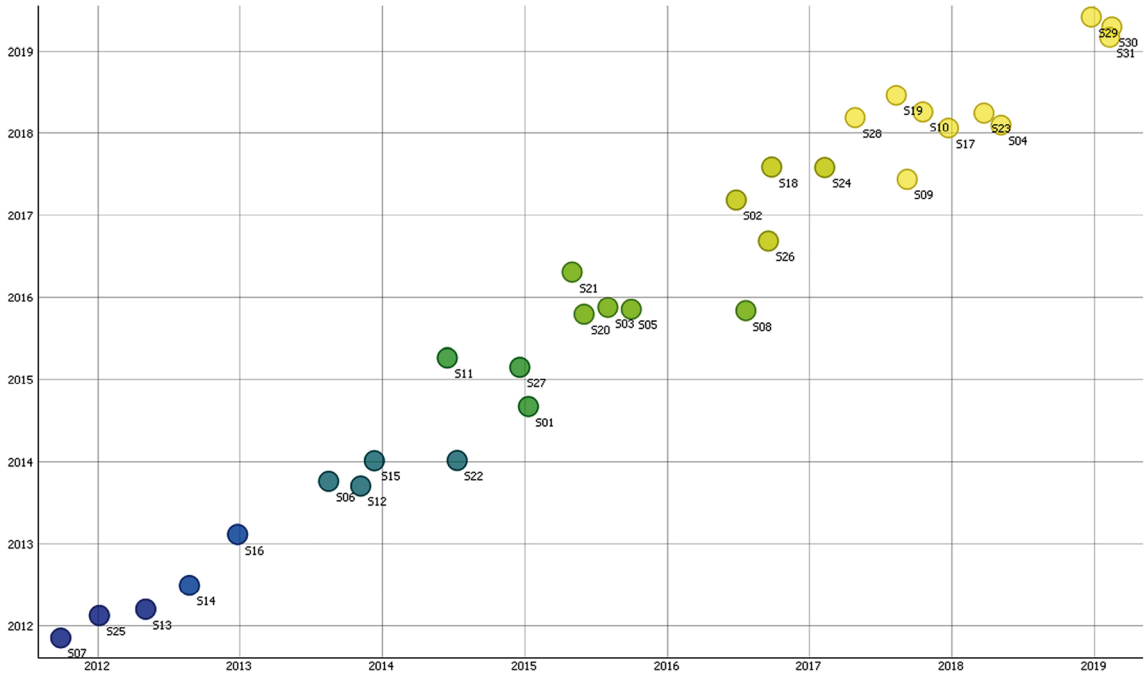

Fig. 5 Distribution of primary studies by publication year. The scatter plot shows the publications found between 2012 and 2019

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

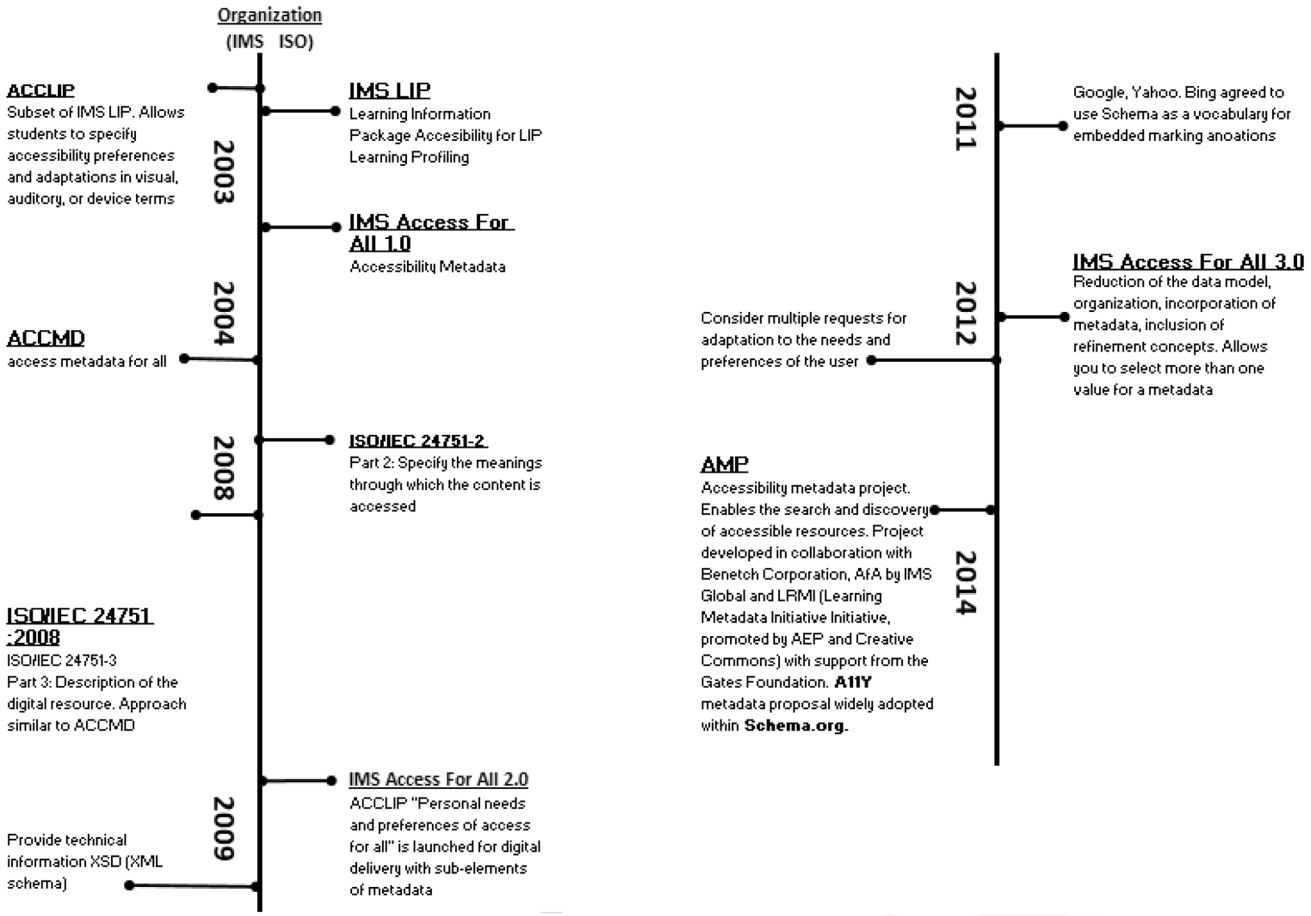

Fig. 6 Timeline of accessibility metadata. The graph shows a timeline in the history of accessibility metadata

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

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2.2 Artículo II: Accessibility Challenges in OER and MOOC: MLR Analysis Considering the Pandemic Years

El presente estudio establece una revisión de modelos de accesibilidad en Recursos de Aprendizaje Abiertos - OER y MOOCs, con el fin de establecer términos comunes en la investigación del proyecto EduTech y proyectos asociados con accesibilidad virtual en las Instituciones de Educación Superior. La revisión bibliográfica está basado en la investigación de artículos y publicaciones relacionados con la temática siguiendo el formato Multivocal Literatura Review MLR.

2.2.1 Contribución

El articulo se fundamenta en datos de literatura científica y literatura gris en un período de tiempo restringido, considera el empleo de una metodología rigurosa en el desarrollo de la revisión sistemática. Se formula tres conclusiones principales. En primer lugar, hay una escasez de evaluación de accesibilidad en recursos y cursos educativos virtuales, avalado por personas con discapacidad. Además, los estudios disponibles tienden a centrarse más en las recomendaciones de diseño que en evaluar la efectividad de su implementación y proceso de mejora. En segundo lugar, el uso de estándares de accesibilidad es subjetivo, en varios casos responde a modelos evaluativos que, si bien consideran la accesibilidad como métrica evaluativa, resulta inconsistente llegar a un proceso de implementación común, en especial con cursos que sobrepasan la legislación de un país. En tercer lugar, hay una falta de referencias que establezcan una muestra importante de estudiantes con discapacidad, su seguimiento, monitoreo y proceso y mejoramiento en el diseño del aprendizaje, lo cual requiere un mayor tiempo para obtención de datos de confiabilidad. Las diferentes respuestas que surgieron durante el proceso de revisión identifican direcciones prometedoras para futuras investigaciones en la temática. En resumen, el artículo señala los diversos modelos, estándares y herramientas empleadas para la aplicación de recursos de aprendizaje y MOOCs accesibles, información que puede ayudar a otros investigadores a considerar el incorporar la temática de accesibilidad en la creación de recursos con características “abiertas” La publicación de información de accesibilidad en recursos educativos, objetos de aprendizaje y MOOCs tiene una gran influencia en la efectiva respuesta de motores de búsqueda personalizada acorde a necesidades y preferencias del usuario. Se concluye que, si bien los aportes a lo largo de la historia han

generado estándares y normativas que han motivado la investigación en el tema, se carece de una implementación idónea y uso frecuente para su aplicación, sobre todo en países en desarrollo. La información de estudios cuantitativos, cualitativos o mixtos es insuficiente para determinar el impacto en estudiantes con discapacidad a nivel general, por lo que se requiere de un proceso de auditoría y mejoramiento continuo que involucre y comprometa a todos los actores dentro de un proyecto educativo que sustenta un MOOC y sus recursos de aprendizaje.

2.2.2 Artículo

sustainability

MDPI

Article

Accessibility Challenges in OER and MOOC: MLR Analysis Considering the Pandemic Years

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Abstract: The review of state of the art on creating and managing learning resources and accessible Open Educational Resources (OER) and Massive Open Online Courses (MOOC) is a topic that cannot only consider formal literature. The evidence and lack of a measurement consensus require the inclusion of contextual information, corroborating scientific results with practical experiences. For this reason, this article presents a review of accessibility models, OER and MOOC, considering the gray literature to capture experiences and trying to establish a shared understanding of the terminology commonly used in research on virtual accessibility and its impact on higher education. The bibliographic review relies on analyzing articles and scientific publications related to the topic following the Multivocal Literature Review (MLR) format. The results of this review establish that it is possible to apply accessibility review methodologies with transversal actions in the creation and management of learning resources and MOOCs. The research is related to one of the seventeen sustainable development goals defined by the United Nations to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Keywords: accessibility; MOOC; disability; e-learning; multivocal literature review

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1. Introduction

The exponential growth of e-learning and virtual education has led to the accelerated development of teaching and learning resources in which we find a huge diversity in how they are generated and managed as well as student interaction and learning.

One of the seventeen sustainable development goals (SDG 4) defined by the United Nations is to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" [1]. To achieve this goal, education must be of quality and accessible, in the sense of accessibility described above, because accessible education gives people with disabilities the opportunity to learn under equal conditions [2].

Establishing the relationship between the concepts expressed by terms associated with learning resources, learning objects, digital multimedia resources, is critical nowadays given the importance of their use in virtual learning environments.

Relevant research from Europe and Latin America provides guidelines for the creation and management of accessible learning resources. For the present study, experiences of Latin American and European institutions are considered. The review of articles reveals that several accessibility indicators involved in learning resources and Massive Open Online Course (MOOC) are related to Web Content Accessibility Guidelines (WCAG) compliance, usability, user experience, learning design, and quality standards.

The results of the research have shown that accessibility is transversal to the evaluation of educational resources and is considered within the tools and models to evaluate the methodology of a course and its technical aspects.

This study analyzes concepts and relationships of learning resources, virtual courses, and MOOCs from the accessibility approach, then it reviews related literature and research that answer the research questions, considering academic literature and gray literature. The objectives of this study are as follows:

- RO1: Provide an overview of the current status of initiatives in accessible learning resources and MOOCs.
- RO2: Identify good accessibility practices for the creation and accessible management of learning resources and MOOCs.

The article is organized as follows. Section 2 presents the background. Section 3 describes the research methodology. Section 4 provides an analysis of the results, while Section 5 contains a discussion and recommendations. Finally, Section 6 presents the main conclusion of this study.

2. Background

The concept of learning object was first introduced in 1994 by Hodgins, who defined it based on the intersection of three basic design principles: discoverability, reusability, and interoperability [3]. This premise of being easily reusable received wide acceptance by the scientific community [4]. Technological progress and the increased use of digital resources in the mediation of learning, caused the concept to evolve quickly. The definition of learning object by [5] as a " . . . entidad digital, autónoma y reutilizable, con una clara finalidad educativa, constituida por al menos tres componentes internos editables . . . " (. . . digital entity, self-contained and reusable, with a clear educational purpose, constituted by at least three editable internal components . . .), and the constant coincidence in the characteristics of identification, recovery, detectability, reusability, and interoperability; helped researchers to delimit the concept even further. However, it has also allowed to understand the variability and cultural evolution of its practice in virtual learning environments. As the concept evolved, the consideration of the legal aspects involved became paramount and reuse licenses were established. At the turn of the millennium and ever since the concept merged with the principles of open education, which gave rise to the notion of OER (Open Education Resource) (The origin goes back to a UNESCO Forum held in 2002. http://web.archive.org/web/20021019010259/http:/www.unesco.org/education/news_en/080702_free_edu_ress.shtml accessed on 14 February 2022). The term "open" represents a cultural change in the design philosophy, which can be best summarized in five major additional features established by Wiley and Hilton [6] as the 5Rs. Users of OER should be able to retain, reuse, revise, remix, and redistribute the content. Figure 1 points out the main characteristics of these 5Rs:

In the Paris Declaration of 2012 [7], UNESCO recommends member states to "promote quality assurance and peer review of OER. Encourage the development of mechanisms for the assessment and certification of learning outcomes achieved through OER". The World Education Forum 2015 [8] in its Education 2030 Declaration states that "Information and communication technologies (ICTs) need to be harnessed to strengthen education systems, knowledge dissemination, access to information, effective and quality learning, and more efficient service delivery". With this, the desirable characteristics of an OER are open access and author acknowledgement.

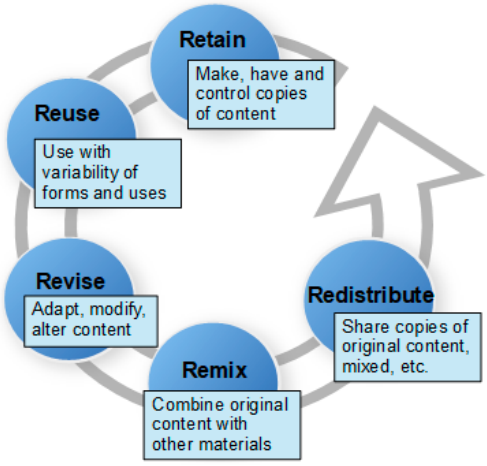


Figure 1. OER 5"R" for Wiley.

2.1. Massive Open Online Course—MOOC

The acronym MOOC was coined by Dave Cormier in 2008, to refer to the course "Connectivity and Connective Knowledge" offered by Stephen Downes, senior researcher at the National Research Council of Canada, and George Siemens associate director of research and development at the University of Manitoba [9,10]. The main feature of a MOOC responds to an open online course with massive student participation. The materials of a MOOC could be protected by copyright—xMOOC or use and create OERs under Creative Commons license—cMOOC [4]. Several researches seek to classify or evaluate MOOCs. Based on learning characteristics, [11] notes that an iMOOC could highlight its focus on individual responsibility, interaction, interpersonal relationships, innovation, and inclusion, or provide a learning experience marked by social interactions and participation considered as sMOOC [12,13]. The study [14] also adds the bMOOC as a recent combination of the advantages of the online MOOC and the need for face-to-face interaction. See Figure 2.

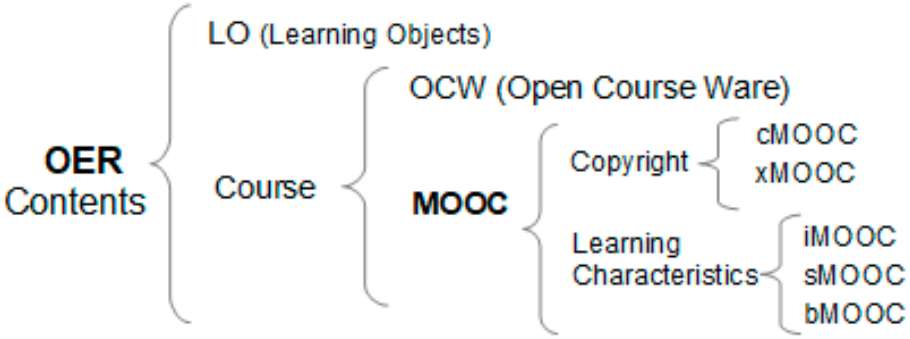


Figure 2. OER and MOOCs relationship.

The relationship between OER and MOOCs converges in that the identification of their content is treated individually as a learning object or within a course [15]. Courses can be complete, open but with recognized copyright, usually from a university institution OCW; or open, massive, and online courses, such as MOOCs.

Accessibility is transversal in any of the defined components such as LMS, digital resources, learning objects, virtual learning environments, and/or virtual courses and everything that converges in MOOCs and OER.

2.2. Accessibility

Accessibility is related to several concepts that seek to facilitate the development or use of something in particular, among them: flexibility, customization, universality, usability, interoperability, reusability, and navigability. The standard ISO/IEC 24751-2, defines

accessibility as "Usability of a product, service, environment or facility by individuals with the widest possible range of abilities" [16].

There are several considerations to take into account to make viable or prevent the access of a person with a disability, such as:

- Hearing impairment, oral, and/or sonorous expression generates problems in understanding the environment. Written comprehension is usually limited, mainly in those who lost their hearing ability before learning to speak. Captioning, use of pictures and diagrams, sign language are required.
- Physical disability: Those in this group are considered those who have problems with transfer, movement, or coordination in handling objects. Mouse movement and clicking may be complex or limited features.
- Visual impairment: Graphic information makes comprehension difficult if there is no textual-aural alternative. Small font sizes and inadequate contrast management affect navigation. Interaction is usually with a keyboard.
- Intellectual disability: Difficulties in understanding, assimilating, or retaining information. Interpretation of symbolic language and guidance may be complex. A simple vocabulary, simple syntax, and the use of headings, standardized pictograms, and lists of categories are fundamental elements in the understanding of users.

It is important to consider that there are people who, even if they do not have a permanent or temporary disability, have difficulties in accessing information, such as those who do not know about technology or do not have the optimal technology, temporary accidents, as well as older adults who are losing skills in interacting with a computer.

2.3. Related Works

The standards development establishes rules and requirements that must be met, making it possible for resources to be platform-independent, strengthening their interoperability, reusability, durability, updateability, scalability, among others. This generates standards for various areas related to learning resources and MOOCs.

Accessibility in e-learning is not only framed in technology and its interaction, it also requires feedback from the design of learning experiences for all, considering not only technology and pedagogy but also ethics [17].

Methodological proposals focused on the quality of virtual educational resources are based on ISO standards, establishing guidelines for applying ICTs in teaching. However, some studies [18,19] identify the lack of an accessibility methodology with a holistic and adaptive approach.

Standards such as [20–22] establish guidelines that are related to accessibility; however, the applicability and dissemination are still limited. In several Latin American countries, the use of standards of private organizations is not possible until they are considered official standards such as ISO, which is why the WCAG could not be adopted until 2012 when the standard [23] Information Technology—W3C Web Content Accessibility Guidelines (WCAG) 2.0 was created.

Some projects have been developed to favor accessibility in virtual environments. The shared experiences EU4ALL [4], ESVIAL [18], TILE, AEGIS, ACCESSIBLE [24], and OBBA in Brazil [25], to mention a few, highlight research and implementation efforts to favor educational inclusion. In parallel, the evaluation of learning resources and MOOCs generates proposals for models and standards to be applied, for which the accessibility criterion is considered relevant, but has not yet achieved a consensus of information.

Currently, universities face the challenge of providing quality education by strengthening the inclusion approach and addressing the high rates of exclusion, discrimination, and educational inequality. The creation of conditions for the development of education for all, which guarantees quality with equity, implies transformations in the educational system of HEIs, in their cultures, policies, and practices, involving an active and participatory manner evaluative processes that validate the efforts made. In [26], the Convention on Human Rights and its Optional Protocol states in Article 24: "States Parties recognize the

right of persons with disabilities to education. With a view to realizing this right without discrimination and on the basis of equal opportunity, States Parties shall ensure an inclusive education system at all levels as well as lifelong learning".

Regarding the main MOOCs platforms identified, it is established that out of a total of 12 (EDX; CUORSERA; UDEMY; FUTURE LEARN; UDACITY; MIRIADAX; NOVOED; UNED; KHAN ACADEMY; TUTELLUS; CREHANA; LYNDA), only four have accessibility policies. See Table 1.

Table 1. Accessibility policies in MOOCs.

MOOC	Accessibility Policies
EDX	https://www.edx.org/es/accessibility (accessed on 20 December 2021)
COURSERA	https://learner.coursera.help/hc/es/articles/209818883-Pol%C3%ADtica-de-accesibilidad-de-Courserahttps://learner.coursera.help/hc/es/articles/208280056-Adaptaciones-para-estudiantes-con-discapacidades (accessed on 20 December 2021)
FUTURE LEARN	https://about.futurelearn.com/terms/accessibility-policy (accessed on 20 December 2021)
UNED	https://blogs.uned.es/unedabierta/canal-fundacion-once/ (accessed on 20 December 2021)

3. Materials and Methods

The review of the state of the art on the creation and management of learning resources and accessible MOOCs is a topic that cannot only consider formal literature; the evidence and lack of a measurement consensus require the inclusion of contextual information, corroborating scientific results with practical experiences. With this, the incorporation of Grey Literature (GL) within the structure of the review protocol with the Multivocal Literature Review (MLR) methodology based on Systematic Literature Review (SLR) [27].

3.1. Conducting the Review

The following research questions (RQ) were formulated based on the research objectives (RO) outlined above:

RQ 1: How are accessible learning resources created and managed?

This question is posed by the diversity of existing accessibility practices in accessible resources.

To answer this RQ, relevant previous studies on accessible learning resources and the educational institutions that influenced their development were analyzed.

RQ 2: Can accessibility be mainstreamed in MOOCs?

The question is posed to establish the phase in which accessibility is considered within the creation of a MOOC.

To answer this RQ, comparative studies of MOOC accessibility and the establishment of policies or standards applicable in MOOCs were analyzed.

RQ 3: What models have been used to promote accessibility in MOOCs and learning resources?

The question is asked to establish models frequently employed when approaching accessibility in MOOCs and learning resources.

To answer this RQ, this study investigated the models employed on various platforms by identifying best practices, learning outcomes, and satisfaction.

RQ 4: What are the challenges and opportunities that have been addressed in the creation and management of accessible educational resources and MOOCs with experience in the pandemic?

The question seeks to establish current and future research trends on the subject of accessibility in educational resources and MOOCs.

To answer this RQ, this study investigates the limitations of existing tools and systems related to accessibility in educational resources. It also summarizes and provides recommendations used in the pandemic.

The search string identified in this study is

(ACCESSIBILITY) AND (MOOC) AND ("OPEN EDUCATIONAL RESOURCES" OR "OPEN EDUCATION RESOURCES" OR "LEARNING OBJECT").

For academic literature, the search engines used are:

ACM, SCOPUS, IEEE, ERIC, AND GOOGLE SCHOLAR.

For GL literature, GOOGLE and pages identified by their reports on the subject of accessibility and virtual education were used.

3.2. Study Selection Criteria

After completing the search string, the following criteria were considered as inclusion criteria in the academic literature (see Figure 3):

- Must have been published in the period from January 2013 to December 2021.
- It must be written in English or Spanish.
- The article must be related to accessibility strategies in educational resources and MOOCs.
- The article must respond to relevant research in the partner countries or of high connotation in accessibility issues.

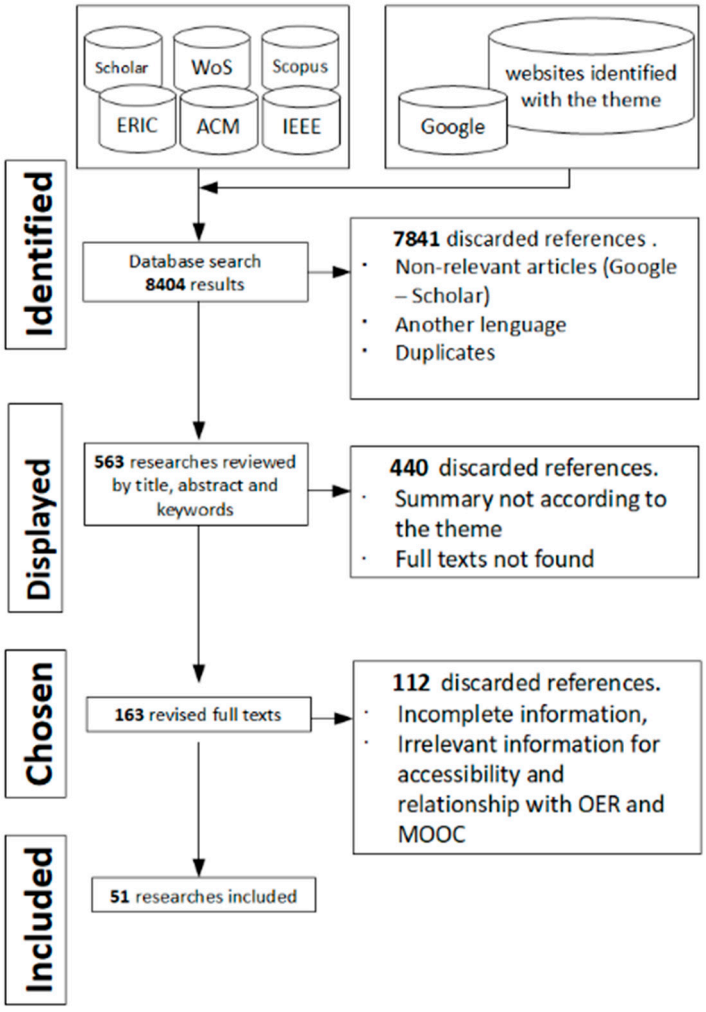


Figure 3. Process of study selection criteria.

As exclusion criteria in academic literature are considered:

- Papers that are not related to accessibility and experiences in virtual education.
- In Google Scholar, the 200 most cited (citation index >40) are considered.

In gray literature and Google, after fulfilling the search string, the following are considered as inclusion criteria:

- The first 100 searches.

As exclusion criteria in gray literature are considered:

- Commercial advertisements and images.
- Documents not related to accessibility and experiences in virtual education.
- Broken links or with access to purchase books.

Assessment Criteria for Study Quality and Result

Table 2 establishes the questions to evaluate the quality of each study. In (QA1) the prestige of the author is evaluated, where it is detected that all of them comply with the identification of the author and experience in the area. The second criterion (QA2) evaluates the data collection and procedures that respond to a research methodology and it is concluded that 31 articles present clear objectives and methodological process supported by reliable references limited to a particular population or situation, 20 present a description of the proposed approach, but lack reliable references or scarce delimitation of the topic. The third criterion (QA3) examines the objectivity presented, it is concluded that out of 41 articles, the content of the source is discussed and supported by data, while ten allude to a discussion; however, the opinion is not impartial or is not supported by real data. The fourth criterion (QA4) evaluates whether the source presents a clear date of elaboration, to which 43 specify a clear date, seven refer to a period but do not establish a specific date, and one does not present the date of elaboration. The fifth criterion (QA5) evaluates whether there is an unpublished and significant contribution to the research, concluding that 34 articles contribute innovation, 14 articles reinforce current ideas but do not contribute something unique to the research, and three articles do not contribute innovation or novelty.

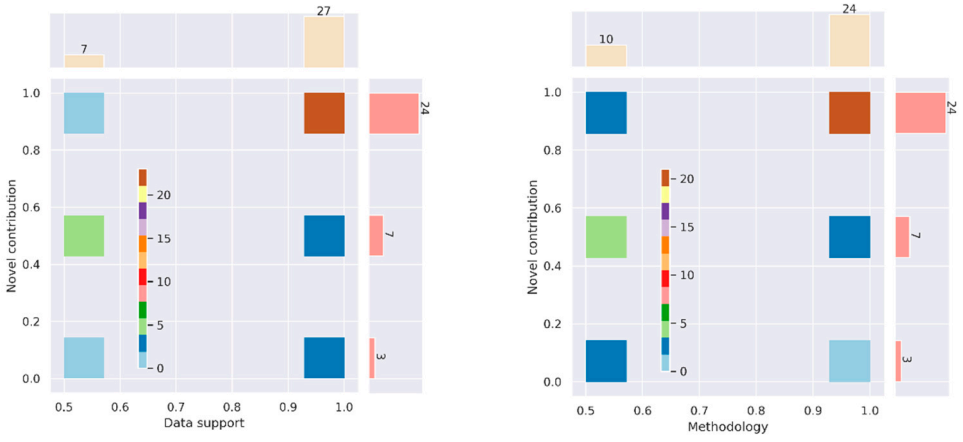
In order to determine how the publications in the academic literature studied are related, a statistical analysis was performed with four pairs of quality questions. As can be seen in Figure 4, part (a) compares the results obtained in questions QA5 (Novel contribution) and QA3 (Data support). In this sense, we can see that 27 and 24 publications have a maximum evaluation (1) for each question, respectively. Meanwhile, seven papers have a mean value (0.5) and three publications with a minimum value (0) for each question. On the other hand, part (b) compares the evaluations of the articles with respect to questions QA5 (Novel contribution) and QA2 (Methodology). In this case, it can be seen that 21 articles receive a maximum score in the two questions, having seven with the maximum combination for QA2—mean QA5 and vice versa and three articles with the minimum combination. This in general terms gives us a clear guideline of the quality of the publications that have been studied, and how they respond to the quality questions that have been previously established.

In the case of GL, the criterion of type is added for its quality evaluation and it is concluded that 12 articles are of the first level because they correspond to books and journals of scientific dissemination and specialized foundations and one is considered of the second level because it is a presentation. The same analysis was performed as in the case of academic literature. Figure 5 compares the results obtained in questions QA5 (Novel contribution) and QA3 (Data support). Here it can be seen how the publications have a lower score in the different combinations. For example, most of the articles (7) score high for QA3 and medium for QA5. This result is perfectly aligned with aspects of scientific rigor that occur more frequently in the case of academic literature. Meanwhile, it also compares the evaluations of the articles with respect to questions QA5 (Novel contribution) and QA2 (Methodology). In this case, it can be seen that the same phenomenon is present

where the most important evaluations are the averages (7). However, it is important to note that in the case of the gray literature there are no zero evaluations, while in the academic literature there are such values.

Table 2. Quality question list.

Item	Assessment Criteria	Description of Checklist
QA1	Is the author's recognition clearly identified or associated with a recognized organization based on the experience of the subject?	Yes. Authorship and expertise are clearly identified. No. The authorship data is not identified. Partially. Presents data, but does not specify evidence to support the experience.
QA2	Is the research methodology clearly identified?	Yes. It presents clear objectives and a methodological process supported by limited reliable references in a particular population or situation. No. It lacks identification of a research methodology. Partially. Presents a description of the proposed approach, but lacks reliable references or little delimitation of the topic.
QA3	Is the target's support adequately described in an unbiased way?	Yes. The content of the source is discussed and supported by data. No. Lack of supporting data. Partially. It alludes to a discussion, however, the opinion is not impartial or is not supported by real data.
QA4	Does the source present a clear date of its elaboration?	Yes. The date is present. No. Does not present an elaboration date. Partially. It refers to a period but does not set a specific date.
QA5	Is there an unprecedented and significant contribution to the research?	Yes. The source provides innovation and reinforces or refutes current ideas on the subject. No. The font does not provide innovation or novelty. Partially. It reinforces current ideas but does not contribute something unique to the research.



(**a**) (**b**)

Figure 4. Academic literature quality evaluation.

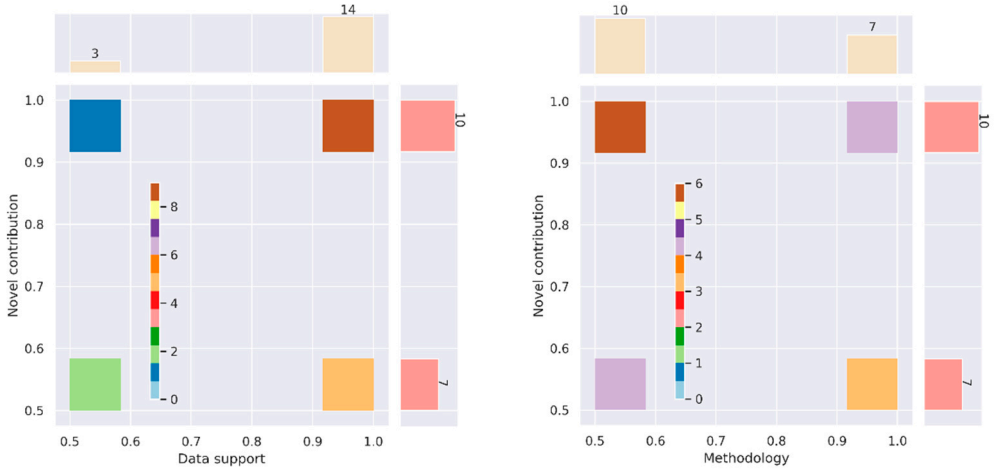


Figure 5. Gray literature quality assessment.

4. Results and Analysis

The identification of relevant studies that were selected for this study are included in the analysis for subsequent discussion with respect to RQs.

4.1. Conducting the Review

The following research questions (RQ) were formulated based on the research objectives (RO) outlined above:

Out of all the studies, 43% of the selected articles were published in scientific journals, while 26% belong to high impact conferences, 29% are articles and papers on the internet, which constitute the majority of the grey literature. The results of the 51 studies analyzed in this research are presented in Appendix A. Each result is presented according to the corresponding research question. Figure 6 shows the distribution of articles according to the year of publication.

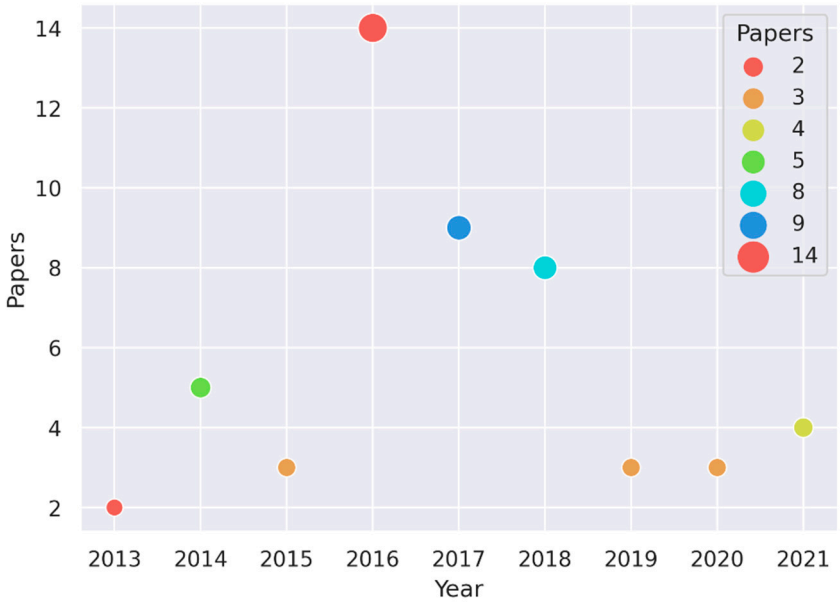


Figure 6. Distribution of studies by year of publication.

The volume of publications increased in 2016, a period in which local legislation establishes compliance with accessibility regulations so that virtual courses and research

on the subject take a greater interest. Table 3 shows the studies grouped by the answers to the research questions.

Table 3. Studies grouped by the answers to the research questions.

Research Question	Total Responses	Study ID
RQ1	19	S02, S03, S04, S06, S07, S08, S10, S11, S12, S14, S15, S16, S37, S38, S40, S42, S43, S46, S47.
RQ2	9	S02,S04, S05, S09, S17, S28, S29, S41, S45, S50.
RQ3	27	S01, S02, S04, S06, S08, S09, S10, S11, S13, S14, S15, S16, S17, S20, S21, S22, S23, S24, S25, S26, S27, S28, S29, S32, S36, S41, S43, S48.
RQ4	36	S01, S02, S03, S04, S6, S7, S10, S11, S12, S14, S15, S17, S18, S19, S21, S22, S24, S29, S30, S31, S33, S34, S35, S36, S37, S38, S39, S41, S44, S45, S46, S47, S48, S49, S50, S51.

4.2. RQ1: How to Create and Manage Accessible Learning Resources?

Since their emergence, OER have proposed several categorizations based on usage rights, applicability to learning design, and their benefits, which has generated a changing conception [28]. The digital educational material will have the purpose of integrating a sharable collection in an educational environment, so they must comply with characteristics that facilitate their reuse, interoperability, and accessibility.

The creation and management of accessible learning resources cover several components depending on their typology. We can have documents, PDFs, presentations, spreadsheets, videos, audios, glossaries, images, forms, and other interaction elements. As there is a range of possibilities of accessible learning resources, some authors [25,29] suggest the integration of metadata according to profiles, adding accessibility features. The establishment of profiles feeds back to the learner's needs and preferences [30]. However, determining a profile does not always respond to developing adaptations to a particular material, as stated by [4], when determining that students made more mistakes when requesting pre-established adaptations. It would be more ideal to provide accessibility information to serve all students.

The evaluation of the level of accessibility and usability according to [4] is proposed from the quantification of aspects of efficiency, effectiveness, and satisfaction, for which it proposes a methodology based on a joint evaluation of WCAG and ISO 9241-11. Some authors [31–33] argue the need for accessibility evaluation in resource management and the generation of new resources from them. Ref. [17] points out the importance of considering the level of understanding perceived by different user profiles according to the pedagogical objective, thus establishing that the level of accessibility should be measured as a package. The evaluation process requires scenario validation to illustrate and explore accessibility issues [34]. Literature states that the creation and management of accessible resources are composed of phases each in a constant process of continuous improvement [35]. The establishment of techniques, models, and methodologies in many cases responds to local, national, or country realities and their pedagogical context, so the subject of accessibility and inclusion covers various cultural contexts and awareness of the problem [36]. Literature also points out the importance of the organization and its technological infrastructure to ensure proper interoperability with assistive technology, as well as support for teachers in creating, publishing, and searching for accessible learning resources [37–39]. The design of inclusive resources requires the application of principles or strategies that support the teacher in the process of generating accessible material for their students. Some works [40,41] propose the application of Universal Design Learning (UDL). Several existing investigations on OER tend to focus on the evaluation of accessibility and usability, little attention has been paid to support the participation of students with disabilities in OER that according to the principles of UDL consider the participation of the student through of various representations [42].

As an answer to this question, it is concluded that the creation and management of accessible learning resources go beyond the technological use of tools. It is required to understand the synergy that must exist between technology and methodological design to establish a coherent creation and management that allows sustainability and contemplates standards and constant updating scenarios such as ubiquitous computing and its relationship with many devices and simultaneous systems.

4.3. RQ2: Can Accessibility Be Mainstreamed in MOOCs?

A study [10] established the life cycle of a virtual educational project requires constant feedback from successful experiences, so there is no common formula to follow [18]. MOOCs facilitate open education, so they are considered an innovative way to change education [28]. LMS virtual environments claim to comply with accessibility standards at the interface level; however, the evolution towards graphical and interactive webs increases complexity and interaction [29]. It is necessary to consider that the authoring tools must facilitate accessibility as part of the design and development of educational resources, considering accessibility checklists to evaluate the resources [43].

Another study [10] considers several challenges in the implementation of accessibility in MOOCs, among them the use of guidelines, specifications, and standards [4], the definition of architectures for MOOCs that take advantage of accessible content, providing educational material in various alternative formats, the definition of design patterns, testing compliance with accessibility requirements at the platform and content level, real user testing, sharing accessibility reviews at the public level, among others. Ref. [40] established a scenario-based approach to identify challenges and current practices in discussing possible solutions, considering that accessibility in MOOCs and learning resources, mainly depend on an institutional agenda of inclusion. Involving educators, content generators, and students feeds back into the development and evaluation of a course. Accessibility is not only legal compliance of guidelines, it requires an inclusive design analysis that allows to positively promote the needs and preferences of students [29]. MOOCs have the challenge of offering agile, fluid, and rhizomatic learning opportunities that favor inclusion and the common good [44].

Work [45] establishes that accessibility is not a priority parameter when establishing a MOOC, which is proven by performing 288 accessibility tests in eight recognized MOOC platforms, for which they use automatic tools and expert evaluation, establishing that more than 50% do not meet success criteria of levels A and AA. eDX and FutureLearn are considered as the best scored. From this research it is concluded that nine level A and three level AA criteria are less fulfilled by MOOCs and these are Table 4:

Table 4. Accessibility criteria at level A and AA frequently breached in MOOCs.

Level	Criterion	Description
A	1.3.1.	Information and relationships: The information, structure, and relationships communicated through the presentation can be determined by software or are available as text.
A	4.1.2.	Name, role, value: For all UI components (including, but not limited to: form elements, links, and script-generated components), the name and role can be determined by software; the states, properties, and values that can be assigned by the user can be specified by software; and changes to these elements are available for consultation by user agents, including technical aids.
A	2.4.1.	Avoid blocks: There is a mechanism to avoid content blocks that are repeated on multiple web pages.
A	3.3.2.	Labels or instructions: Labels or instructions are provided when content requires user input.
A	4.1.1.	Processing: In content implemented using markup languages, elements have full opening and closing tags; the elements are nested according to your specifications; the elements do not contain duplicate attributes and the IDs are unique, except where the specifications allow these characteristics.
A	1.1.1.	Non-textual content: All non-textual content that is presented to the user has a textual alternative that serves the same purpose.

Table 4. *Cont.*

Level	Criterion	Description
A	2.1.1.	Keyboard: All content functionality is operable through a keyboard interface without requiring a certain speed for each individual keystroke, except when the internal function requires input that depends on the path of user movements and not just the start and end points.
A	1.2.1.	Audio-only and video-only (recorded): For recorded audio-only content, an alternative is provided for time-dependent media that presents equivalent information for recorded audio-only content. For recorded video-only content an alternative to time-dependent media is provided or soundtrack is provided that presents information equivalent to the content of the recorded video-only medium.
A	2.4.4.	Purpose of the links (in context): The purpose of each link can be determined with only the text of the link or through the text of the link added to the context of the link determined by software, except when the purpose of the link would be ambiguous for users in general.
AA	1.4.3.	Contrast (minimum): The display of text and text images has a contrast ratio of at least 4.5: 1.
AA	1.2.5.	Audio description (Recorded): An audio description is provided for all recorded video content within synced media.
AA	2.4.6.	Headings and tags: Headings and tags describe the topic or purpose.

It is concluded that it is possible to mainstream the accessibility of MOOCs, for which it is necessary the involvement of several instances, both from the organizational and institutional part, as well as creators, designers, academics, and constant feedback from students. Constant practices of application and evaluation of accessibility contribute significantly to a culture of inclusion.

4.4. RQ3: What Models Have Been Used to Promote Accessibility in MOOCs and Learning Resources?

OERs and MOOCs need to be seen from the need to evaluate their quality, focused on their own dimensions of an educational training in its process and result. Ref. [28] states that, from an innovation perspective, MOOCs go beyond OER, since they facilitate processes and experiences.

Establishing models, regulations, standards on the subject of accessibility and virtual education, places us in a similar context and with it, a starting point that goes from the general to the specific. At a general level, we find WCAG with guidelines and recommendations on the subject of web accessibility [46], a requirement to be considered both in MOOCs and learning resources. It is in the interaction of the student with a virtual learning environment and its resources, which leads to seek solutions that effectively respond to various issues. Research and their proposals of models and techniques converge on similar points such as: decrease of barriers [34,47–49], quality assessment [4,50], user experience feedback [39,49,51–53], personalization and recommendation [11,38,54,55], and effective publication of accessibility information [24,56].

Europe's experience in the field of MOOCs research and accessible resources is latent, as evidenced by the number of MOOCs offered and especially Spain, whose legislation regulates the mandatory compliance in public institutions [25]. With this, the legal structure is a fundamental requirement when guaranteeing accessible and quality virtual education for all [10,40,57].

Socialization, awareness, and the development of specific competences [41] in all actors [18,29] who contribute in an accessible virtual course, is an indispensable requirement to generate accessibility culture. The identification of roles and responsibilities converge for the sustainable implementation over time of a model that promotes accessibility in MOOCs and learning resources.

In response to the research question, it is established that the various models to promote accessibility in MOOCs and learning resources are based on regulations and standards that seek to ensure the didactic and technological effectiveness of resources, which contributes to quality processes considering accessibility as an evaluative parameter.

4.5. RQ4: What Are the Challenges and Opportunities That Have Been Addressed in the Creation and Management of Accessible Educational Resources and MOOCs with Experience in the Pandemic?

We are still going through the pandemic situation, so several educational experiences in e-learning have been generated on the fly, remembering that all students, whether they have disabilities or not, have the right to access an online educational environment designed to help them reach their maximum potential. Although the year 2012 was called the year of MOOCs, the pandemic marked another milestone, also the UNESCO OER recommendation for the implementation of its five areas encourages strengthening its use in education [44]. In the results report on the effects and consequences of the COVID crisis, it indicates that 65% of those consulted have dedicated time to training compared to previous reports whose percentage was reduced to 23%, pointing out that it is necessary to improve accessibility and diversity of topics of the training platforms, avoiding specific courses for people with disabilities [58].

At a general level, the research highlights the lack of dominant studies on the production of MOOCs and OER in developing countries, thus the experiences of educators and students overlap with global trends that do not reflect a significant contribution in access and training in online learning environments within structural constraints [33,59]. Even more so in a pandemic situation where not everyone was a user of a virtual environment and the demand for tutorials to access or register independently was imminent [60].

International policies and legal and organizational regulations [36] must be taken into account for the management of those involved [34,44,61]. The wide range of disabilities, the variability in learning, and their modes of interaction [34] suggest performing deeper analyses of the wide variety of assistive technology and their technical issues [24,48] fed back to the user experience by developing a holistic approach [51] and measuring the scope and subsequent benefits of those involved [30]. OER-based pedagogy is proposed as future research, for which, [42] points out the importance of collecting information on related instructional practices, where learning experiences are deepened.

There is a need to support models with more robust analyses of access, interaction, and feedback of students with disabilities [29,50,62]. However, under a virtual educational world in a pandemic, the contributions of accessibility, usability, UDL, present interesting aspects of analysis such as: providing different forms for involvement, consistent and regular feedback, and establishing spaces to analyze the self-efficacy of the student [49] could positively influence collective learning.

The collaborative approach from which OER and MOOCs are born leads to the joint pursuit of pedagogical and technological challenges to achieve quality-enhanced reconstruction [47,63,64]. It is necessary to evidence defined metrics that endorse methodologies [18] and reference international guidelines or instructions related to design for all [65]. The "open" spirit of MOOCs and OER should evidence accessibility from their creation and management [58,66] guaranteeing didactic and technological effectiveness within a continuous evaluative process.

The incorporation of intelligent systems could contribute to the evaluation of accessible resources and in the feedback of profiles and personalization from the user experience [37,56]. It is necessary to measure the impact and implement processes to identify accessibility barriers, with mechanisms that involve the participation of students in co-design and co-evaluation [43].

The efficient publication of accessibility information would facilitate an optimal search for resources according to learner needs and preferences [32,67].

In response to RQ4, we can say that the field of accessibility is extensive, so the associated techniques and standards need to be homogenized and socialized to generate a multiplier effect on the developers of e-learning resources. The pandemic crisis in many cases shows the lack of time for sufficient training in the adaptation of material and consideration of the most vulnerable groups. However, the opportunities generated to create new ways of teaching and learning through a virtual environment invite the

creation of a new model in which people feel valued and welcomed. It is necessary to share experiences and educational material generated to extend its use through the appropriate use of metadata, so that the learning curve achieves a common language in the development of accessible digital resources that are easy to implement and search on the web.

4.6. Limitations

The present study presented limitations during the process and in its quest to answer the research questions. The selection of research keywords and exclusion criteria were mostly subjective. However, by obtaining a coefficient of 0.743 in Krippendorff's alpha, an optimal level of inter-observer reliability was determined, thus guaranteeing a reduction of bias. The systematic review is based on databases of scientific literature and gray literature and is therefore not completely exhaustive. The omission of articles may also respond to the selected time period 2013–2019 and the consideration of Google as a search engine in the gray literature; however, the bias was reduced by choosing a set of databases covering the main disciplinary fields in which accessibility in MOOCs and OER can be addressed. This study, in its academic literature, focused on journal articles and conferences due to the fact that the topic is addressed in several scientific congresses covering developments in e-learning and accessibility. In the gray literature, it is oriented to search positioning.

Another limitation is the selection of documents written in English and Spanish, so trends in other countries and their current state of research may have been lost. However, it is considered that the systematic review process offers a good overview of the state of research on MOOCs and accessible OER, considering that several topics have been investigated in previous reviews, identifying various relationships in the creation and management of virtual learning environments and accessible resources.

5. Discussion and Recommendations

The present review of the state of the art aimed to provide an overview of the current state of research on the creation and management of accessible OER and MOOCs. The results showed a lack of applicability and data to support the current situation in Latin America; however, the experiences of European projects and regulations that endorse their sustainability, establish guidelines that could guide implementation processes in higher education institutions.

The application of processes that guide accessibility in virtual education still responds to subjective criteria that depend on local or institutional models of evaluation in virtual education and general guidelines. The studies also showed a lack of measurement of the impact on the applicability of accessibility in MOOCS and OERs from the experience of a significant sample of students with disabilities, as well as the satisfactory or unsatisfactory results of their teaching–learning process. Case reports are established with a limited number of subjects. The studies focus essentially on local experiences.

Future Directions

Through the findings, research perspectives, and the challenges posed to improve the field of accessibility in the creation and management of MOOCs and OER, it is relevant to explore the efforts generated to establish models that promote accessibility.

Although some authors [4,50] propose guidelines to mainstream accessibility, it is still complex to answer questions about models and good practices that cover the entirety of a virtual educational process and the inclusion of new features that improve learning design.

The advantages of an adequate implementation of accessibility in MOOCs and OER courses is still not a general domain knowledge, so concluded several authors [19,32]. The publication of accessibility information could favor the correct adoption of practices that generate a future direction that can focus on the effective search for courses and educational resources that respond to the needs and preferences of a student with a disability, considering that the efforts generated to create accessible educational material enriches the universality of education.

The creation and management of accessible educational resources, supported by the degree of satisfaction of a student when interacting, achieve synchrony with resources that can be reused. Undoubtedly, education generates valuable educational material that could favor repositories and enrich the educational process in a virtual environment as it knows no borders and has open availability.

The systematic review places us in the impact of accessible MOOCs and OER. The publications analyzed show an interest in strengthening their implementation. An important need is established in the generation of guides, tools, and techniques that promote their development and strengthen their evaluation and impact in developing countries.

Based on the literature review, it is established that there is no accessibility evaluation model for OER and MOOCs. It is considered that it is necessary to establish accessibility guidelines to assist in the elimination of barriers, so we propose as future work, to explore and investigate the strengths and weaknesses of accessible educational resources, compatibility with assistive technology, and the implementation of guidelines that favor the training of accessible OER to generate a culture of inclusive design.

Although the year 2012 was called the Year of MOOCs [68], now with the pandemic, 2020 marked another milestone in that MOOCs have drastically changed the way people learn and how to access knowledge [44], which entails constant feedback from the community and diversity in learning.

It is necessary to elaborate and implement legal regulations, especially in developing countries. The importance of demonstrating the social and institutional benefits of implementing accessible MOOC platforms and content contributes to optimal quality assessment. More research is needed on the needs not only of specific disabilities, but in the context of the learning experience, platform design, maintenance, and inclusion of new features.

6. Conclusions

Our study was developed in the framework of establishing technical guidelines for the creation and management of accessible learning resources, OER, and MOOCs in the context of Latin American HEIs, with special emphasis on the partner universities of the EduTech project in Ecuador and Mexico.

Despite the limitations of this research, since it is based on data from scientific literature and gray literature in a specific timeframe, we consider that the potential bias was reduced by covering the disciplinary fields of informatics, education, and information search and applicability experiences in developed countries whose legislation supports accessibility in virtual education. We also consider the use of a rigorous methodology in the development of the systematic review, in addition to the analysis of agreement reached among the reviewers, which achieved an optimal level of reliability.

Three main conclusions can be drawn. First, there is a scarcity of information and indicators regarding the evaluation of accessibility of virtual educational resources and courses, which is endorsed by people with disabilities. Moreover, the available studies tend to focus more on design recommendations than on evaluating the effectiveness of their implementation and improvement process. In second place, the use of accessibility standards is subjective, in several cases, it responds to evaluative models that, although they consider accessibility as an evaluative metric, it is inconsistent to reach a common implementation process, especially with courses that go beyond the legislation of a country. Lastly, there is a lack of references that establish an important sample of students with disabilities, their follow-up, monitoring, and process and improvement in learning design, which requires more time to obtain reliable data. The different responses that emerged during the review process allowed us to identify promising directions for future research on the subject.

In conclusion, this study presents the various models, standards, and tools used for the application of accessible learning resources and MOOCs, information that may help other researchers to consider incorporating accessibility issues in the creation of resources with "open" features. The publication of accessibility information in educational resources,

learning objects, and MOOCs bears great influence on the effective response of personalized search engines according to user needs and preferences.

Finally, it is concluded that, although the contributions throughout history have generated norms and regulations that have motivated research on the subject, there is a lack of adequate implementation and frequent use for its application, especially in developing countries. The information from quantitative, qualitative, or mixed studies is insufficient to determine the impact on students with disabilities at a general level, and much more post-pandemic teaching is expected, so the generation of policies and audit processes will be necessary to develop a culture of continuous improvement that involves and commits all the actors within an educational project that considers diversity.

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Appendix A

Table A1. References of studies.

ID Study	Title	Authors	Publication Type	Source	Year of Publication
S01	Accessible platforms for e-learning: A case study. Computer Applications in Engineering Education	Batanero, C., Fernández-Sanz, L., Piironen, A. K., Holvikivi, J., Hilera, J. R., Otón, S., & Alonso, J.	J	Computer Applications in Engineering Education, 25(6)	2017
S02	A preliminary study for developing accessible MOOC services	Iniesto, F., & Rodrigo, C.	J	Journal of Accessibility and Design for All,	2016
S03	A framework for improving web accessibility and usability of Open Course Ware sites	Rodríguez, G., Pérez, J., Cueva, S., & Torres, R	J	Computers & Education	2017
S04	Setting accessibility preferences about learning objects within adaptive elearning systems: User experience and organizational aspects	Rodriguez-Ascaso, A., Boticario, J. G., Finat, C., & Petrie, H.	J	Expert Systems	2017
S05	Research challenges in accessible MOOCs: A systematic literature review 2008–2016	Sanchez-Gordon, S., & Luján-Mora, S	J	Universal Access in the Information Society,	2018

Table A1. *Cont.*

ID Study	Title	Authors	Publication Type	Source	Year of Publication
S06	Metadatos de accesibilidad en recursos educativos: Análisis y propuesta.	Temesio S, Vizoso V.	J	Palabra Clave	2017
S07	An ecosystem for corporate training with accessible MOOCs and OERs	S. Sanchez-Gordon, S. Lujan-Mora S.	c	3rd IEEE International Conference on MOOCs, Innovation and Technology in Education, MITE 2015	2016
S08	OER-based learning and people with disabilities	Navarrete, R. ; Luján-Mora, S.	c	IEEE/IET Electronic Library (IEL)	2016
S09	OLA! a scenario-based approach to enhance open learning through accessibility	Coughlan, T. ; Rodriguez-Ascaso, A. ; Iniesto, F. ; Jelfs, A.	j	Lecture Notes in Computer Science	2016
S10	Accessibility metadata to improve OER adaptability	Temesio S; Motz R	C	Learning Objects and Technology (LACLO), Latin American Conference	2016
S11	Adaptive framework to the search and retrieval of digital educational resources	Tabares Morales V. ; Duque Méndez N.; Rodríguez Marín P. ; Ocampo M.	C	Learning Objects and Technology (LACLO), Latin American Conference	2016
S12	Opening up education: A support framework for higher education institutions	Santos A., Punie Y.	J	econpapers.repec.org	2016
S13	An investigation into the perspectives of providers and learners on MOOC accessibility	Iniesto, F. ; Mcandrew, P. ; Minocha, S. ; Coughlan, T.	c	Proceedings of the 5th International Conference on technological ecosystems for enhancing multiculturality	2017
S14	Developing Teachers?Competences for Designing Inclusive Learning Experiences	Navarro, S; Zervas, P.; Ramon F.; Sampson, D.	j	Journal of Educational Technology & Society	2016
S15	Infraestructura tecnológica para criar, publicar e recomendar recursos educativos abiertos accesibles		j	Revista Observatório	2018
S16	Digital Technology, Learning, and Postsecondary Students with Disabilities: Where We've Been and Where We're Going.	Fichten, C..; Asuncion, J.; Scapin, R.	J	Journal of Postsecondary Education and ...	2014
S17	A framework for improving web accessibility and usability of Open Course Ware sites	Rodríguez, G.; Pérez, J.; Cueva, S.; Torres, R.	j	Computers & Education	2017
S18	Rethinking the accessibility of online higher education: A historical review	Lee K.	J	The Internet and Higher Education	2017
S19	The MOOCs: origin, characterization, principal problems and challenges in Higher Education	Atiaja, LA.; Proenza, R.	j	Journal of e-Learning and Knowledge ...	2016
S20	Supporting openness of MOOCs contents through of an OER and OCW framework based on Linked Data technologies	Piedra, N.; Chicaiza, J. López, E. Tovar C.	c	2014 4th IEEE Global Engineering Education Conference: Engineering Education Towards Openness and Sustainability, IEEE EDUCON 2014	2014
S21	MOOCs A Review of the State-of-the-ArtA	Ahmed Mohamed Fahmy Yousef, Mohamed Amine Chatti, Ulrik Schroeder Marold Wosnitza and Harald Jakobs	C	Proceedings of ... scitepress.org	2014
S22	Formalización de un marco metodológico para la implementación de un proyecto educativo virtual accesible	Amado-Salvatierra, H., Hilera González, J. & Otón, S.	J	Educación XX1, 21(2).	2018

Table A1. *Cont.*

ID Study	Title	Authors	Publication Type	Source	Year of Publication
S23	Can iMOOCs close the Opportunity Gaps?: The contribution of social inclusive pedagogical design	Teixeira, A. M., Mota, J., Pinto, M. do C. T., & Morgado, L.	J	Revista Fuentes	2019
S24	A proposal based on knowledge modeling and ontologies to support the accessibility evaluation process of learning object	Ingavelez-Guerra, P. Robles-Bykbaev, V.Otón, S Vera-Rea, P. Galán-Mena, J., Ulloa-Amaya, M. Hilera, J.	c	Congreso Argentino de Ciencias de la Informática y Desarrollos de Investigación (CACIDI), November 2018, pp. 1–5	2018
S25	Personalized adaptive interfaces for supporting recommendation from learning object repositories	Salazar, O., Rodríguez, P., Marín, D., Ovalle, N., Duque, M.	C	Proceedings of the XV International Conference on Human Computer Interaction	2014
S26	YourMOOC4all: A MOOCs Inclusive Design and Useful Feedback Research Project	Iniesto, F., Rodrigo C.	c	5th International Conference on Learning with MOOCs, LWMOOCS 2018	2018
S27	Using MOOCs to promote digital accessibility and universal design, the MOOCAP experience	Gilligan, J., Chen, W., Darzentas, J.	C	2018 Universal Design and Higher Education in Transformation Congress, UDHEIT 2018	2018
S28	MOOCs for all: Evaluating the accessibility of top MOOC platforms*	Martín, J.; Amado-Salvatierra, H.; Hilera, J.	J	International Journal of Engineering Education	2016
S29	Accessibility of MOOCs: Understanding the Provider Perspective	Iniesto, F., McAndrew, P., Minocha, S. Coughlan, T.	IAWP	paper	2016
S30	Open Education Handbook	Open Education Working Group	IAWP	book	2014
S31	Challenges in Open Educational Resources: The case of TOX-OER MOOC	Morales Martín Ana	IAWP	book	2018
S32	Can user recommendations be useful for improving MOOCs accessibility? A project for inclusive design and profitable feedback	Iniesto, F., Rodrigo C.		presentation	2016
S33	OER and OEP for Access, Equity, Equality, Quality . . .	Ossiannilsson Eba	IAWP	paper	2019
S34	What are the Expectations of Disabled Learners when Participating in a MOOC?	Iniesto, F., McAndrew, P., Minocha, S. Coughlan, T.	IAWP	paper	2017
S35	MOOCs and the claim of education for all: A disillusion by empirical data	M Rohs, M Ganz	C	paper	2015
S36	OER and MOOC: The Need for Openness	Ismar Frango Silveira	IAWP	paper	2016
S37	Advantages and Limitations of Usage of Open Educational Resources in Small Countries	Elena Krelja Kurelovic	IAWP	paper	2015
S38	Validation and open educational resources (OER)	Cedefop	IAWP	book	2016
S39	Adoption and Impact of OER in the Global South | Libro completo		IAWP	book	2017
S40	Guia para crear contenidos digitales accesibles	Hilera, J; Campo, E.	IAWP	book	2015
S41	Tecnología Educativa 2.0: Accesibilidad de plataformas e - learning, recursos educativos y libros electrónicos	Observatorio Accesibilidad TIC discapnet	IAWP	book	2013
S42	Inclusive Open Educational Practices: How the Use and Reuse of OER can Support Virtual Higher Education for All	Teixeira, A., Correia, C., Afonso, F., García, A., Garcí a,E., Otón, S., Piedra, N., Canuti, L., Guzmán, J., Córdova, M.	J	Centro de Filosofia, Faculdade de Letras da Universidade de Lisboa, Portugal	2013

Table A1. *Cont.*

ID Study	Title	Authors	Publication Type	Source	Year of Publication
S43	Are MOOCs Open Educational Resources? A literature review on history, definitions and typologies of OER and MOOCs	Stracke, C.; Downes, S.	j	Open Praxis, vol. 11 issue Open Education Global Conference Selected Papers	2019
S44	MOOCs and OER in the Global South: Problems and Potential	Monty King, Mark Pegrum, Martin Forsey	j	IRRODL The International Review of research in open and distributed learning	2018
S45	A qualitative study to understand the perspectives of MOOC providers on accessibility	Iniesto, F., McAndrew, P., Minocha, S. Coughlan, T.	J	paper	2021
S46	A Scoping Review on Open Educational Resources to Support Interactions of Learners with Disabilities	Jewoong Moon and Yujin Park	J	paper	2021
S47	Accessibility within open educational resources and practices for disabled learners: a systematic literature review	Xiangling Zhang, Ahmed Tlili, Fabio Nascimbeni, Daniel Burgos, Ronghuai Huang, Ting-Wen Chang, Mohamed Jemni and Mohamed Koutheair Khribi	J	paper	2020
S48	COVID-19 Educación inclusiva y personas con discapacidad: Fortalezas y debilidades de la teleeducación	Moreno-Rodríguez, R., Tejada-Cruz, A. y Díaz-Vega, M. (coords.) et al.	IAWP	book	2020
S49	Estudiantes en situación de discapacidad y virtualidad	UNL	IAWP	website	2020
S50	MOOCS for Lifelong Learning, Equity, and Liberation	Ossiannilsson E.	m	IntechOpen	2021
S51	Efectos y consecuencias de la crisis de la COVID-19 entre las personas con discapacidad	Silván Cristina Quífez Luis Enrique	IAWP	Odismet	2021

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2.3 Artículo III: Automatic Adaptation of Open Educational Resources: An Approach From a Multilevel Methodology Based on Students' Preferences, Educational Special Needs, Artificial Intelligence and Accessibility Metadata

El articulo presenta la propuesta de una herramienta de apoyo automatizado en la generación de recursos educativos accesibles que sean correctamente etiquetados para su búsqueda y reutilización. La presente investigación también pretende ser un apoyo a los investigadores en aplicativos de inteligencia artificial para atender desafíos y oportunidades en el campo de la educación virtual, además de brindar una visión general que podría ayudar a quienes generan recursos educativos y mantienen su interés en hacerlos accesibles.

2.3.1 Contribución

El articulo contribuye a sentar las bases para una adaptación automática de imágenes y audios que cumplan normativas de accesibilidad y correcto etiquetado a través de sus metadatos. Se determina que hay una escasez de aplicabilidad de metadatos de accesibilidad en OER. Además, los estudios disponibles tienden a centrarse más en las recomendaciones de diseño que en adaptación efectiva de su para una óptima interacción con estudiantes con discapacidad. El uso de estándares de accesibilidad y metadatos es subjetivo, en varios casos responde a modelos evaluativos que, si bien consideran la accesibilidad como métrica evaluativa, resulta inconsistente llegar a un proceso de implementación común. Se determina una falta de referencias que establezcan una muestra importante de estudiantes con discapacidad, su seguimiento, monitoreo y proceso de aprendizaje, lo cual requiere un mayor tiempo para obtención de datos de confiabilidad. El estudio revela una propuesta de herramientas automática que facilite la implementación de adaptabilidad y accesibilidad considerando sus metadatos, información que puede ayudar a otros investigadores y desarrolladores a incorporar la temática en el modelado de recursos accesibles considerando las necesidades y preferencias del aprendiz. La integración de metadatos de accesibilidad en recursos educativos y objetos de aprendizaje tiene una gran influencia en la efectiva respuesta de motores de búsqueda personalizada acorde a requerimientos de interacción de un recurso educativo. El estudio revela que se

carece de herramientas automáticas que favorezcan la implementación idónea. La información de estudios cuantitativos, cualitativos o mixtos es insuficiente para determinar el impacto en estudiantes con discapacidad por lo que existe datos inconclusos de aplicabilidad en recursos educativos y repositorios de búsqueda.

2.3.2 Artículo

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Automatic Adaptation of Open Educational Resources: An Approach From a Multilevel Methodology Based on Students' Preferences, Educational Special Needs, Artificial Intelligence and Accessibility Metadata

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ABSTRACT The need for adaptive e-learning environments that respond to learning variability is now a fundamental requirement in education, as it helps to ensure that students learn and pass their courses within a set time frame. Although guidelines, techniques and methods have been established in recent years to contribute to the development of accessible and adaptable e-learning environments that promote digital inclusion, their implementation is challenging due to the lack of knowledge of an adequate way to do it and because it is considered more of a technological competence for scholars in the area. In this context, automated support for adapting material that responds to the correct use of accessibility metadata not only provides a way to improve the description of adapted educational resources, but also facilitates their search according to the needs and preferences of students, particularly those with disabilities. In this article, we carry out a multilevel methodological proposal for the automatic adaptation of open educational resources, in order to provide a tool that contributes to the accessibility and correct use of their metadata in e-learning environments. A research is conducted with students with disabilities to establish their real needs and preferences, highlighting the need to strengthen the adequate description and coherent alternative text in images, the correct subtitling in videos and the conversion of audio to text, data that are relevant to our proposal. The research conducted aims to contribute with an automated support tool in the generation of accessible educational resources that are correctly labeled for search and reuse. This research also aims to support researchers in artificial intelligence applications to address challenges and opportunities in the field of virtual education, in addition to providing an overview that could help those who generate educational resources and maintain their interest in making them accessible.

INDEX TERMS Adaptive systems, distance learning, accessibility, metadata, artificial intelligence.

I. INTRODUCTION

The development of technology and its application in education constitutes the constant study of changing and varied innovations. It is necessary to establish a follow-up that supports the whole process, both pedagogical and technological. Currently, virtual learning environments are the best way to offer a complex series of opportunities and tasks to educational institutions in the pursuit of the teaching-learning process, and even more so with the pandemic

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and confinement situation the world is facing. The virtual environment is currently considered the most widely used tool in education, as it allows the distribution of digital educational resources (text, audio, videos, simulators, etc.) that facilitate communication, both in real time and according to the time availability of the user - student. The International Council for Open and Distance Education points out that a total of 414 million students will be enrolled in higher education worldwide in 2030 [1], so the constant study of interaction, learning and requirement for adaptation in e-learning is indispensable.

Accessibility and adaptability in digital educational resources, constantly demands the pursuit for updated research that responds to trends on the variability of student learning and their diversity. Students with disabilities are a valuable source of information in the adaptation requirements for the development of educational material that responds to universal design.

In the case of disability, it is important to consider the worldwide figures and their trend, since around 1 billion inhabitants, or 15% of the world's population, have some type of disability, and its incidence is higher in developing countries [2].

The 2030 agenda for sustainable development [3] determines the commitment to ensure equal access to all levels of education including persons with disabilities, considering inclusive and effective educational environments. 125 countries worldwide have signed and ratified the convention on the rights of persons with disabilities [4], so they face the challenge of providing quality education for all, making viable and strengthening the inclusion approach, addressing the high rates of exclusion, discrimination and educational inequality. The creation of conditions for the development of education for all, which guarantees access to information with equity, implies transformations and adaptations in educational resources, involving active and participatory evaluation processes that validate the efforts made.

The World Education Forum 2015 [5] states that ''Information and communication technologies (ICT) must be harnessed to strengthen education systems, knowledge dissemination, access to information, effective and quality learning, and more efficient delivery of services''.

It is necessary the generation of tools that support the automatic adaptation of digital educational resources, according to the needs and preferences of students. The correct adoption of standards that consider accessibility, not only strengthens quality characteristics, but also provides communication and timely search of desired educational resources, generating satisfaction and fidelity.

This paper presents the analysis of a tool created for adaptation using artificial intelligence techniques and is organized as follows: Section II presents the background and related work so far. Section III provides details of the proposed architecture for automatic adaptation of open educational resources. Section IV presents the analysis of results.

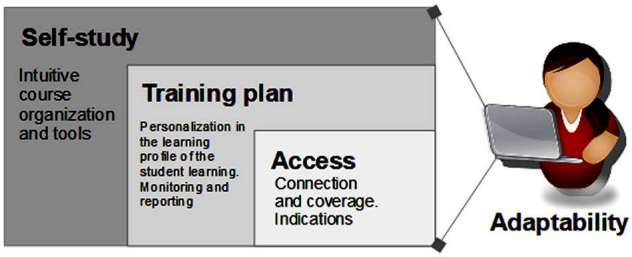

FIGURE 1. Levels of adaptability.

Section V the limitations encountered, and Section VI concludes with the discussion of findings and recommendations.

II. BACKGROUND

The existing relationship between the different digital educational resources that make up a virtual environment and their interaction with the user, demands the establishment of characteristics that allow to analyze the accessibility and adaptability in each of them.

A. ACCESSIBILITY AND ADAPTABILITY

Adaptability and accessibility are two terms that converge when it comes to meeting the diversity of human beings (adaptability), seeking to provide flexibility in their environment (accessibility), so as to accommodate the needs of each user and their preferences.

The ISO/IEC 24751-2:2008 standard, titled ''Information technology – Individualized adaptability and accessibility in e-learning, education and training'', defines accessibility as ''Usability of a product, service, environment or facility by individuals with the widest possible range of abilities'', and adaptability as ''the ability of a digital resource or delivery system to adjust the presentation, control methods, structure, access mode and user support in its presentation'' [6].

The measurement of adaptability in e-learning, according to [7], can be done with indicators defined for three levels, where levels 2 (Training plan) and 3 (adaptability to self-learning) require greater emphasis on diagnostic evaluation, and continues to seek greater effectiveness and efficiency even in the post-training process. (see Figure 1).

Reference [8] considers that accessibility is not only framed in technology and its interaction, it also requires feedback from the design of learning experiences for all, considering not only technology and pedagogy, but also ethics.

B. OER, LO AND METADATA

In 1994 Hodgins defined the concept of learning object and received acceptance for the premise of ease of reuse [9]. Technological progress and the use of digital resources in the mediation of learning, makes its concept evolve constantly. The definition of [10] as ''...digital entity, self-contained and reusable, with a clear educational purpose, constituted by at least three editable internal components...'', and the constant coincidence in the characteristics of identification, recovery,

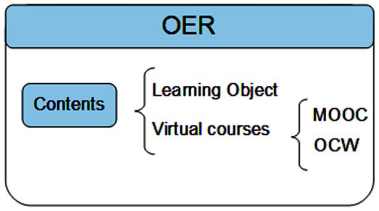

FIGURE 2. Relationship between OER, LO and metadata.

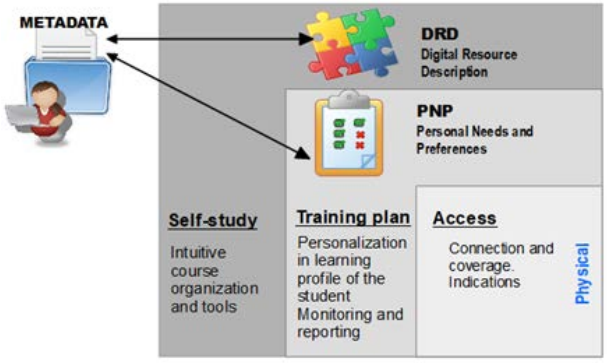

FIGURE 3. Accessibility metadata according to AfA.

detectability, reusability and interoperability; allows delimiting it but at the same time understanding the variability and cultural evolution of its practice in virtual learning environments. It is in this path of evolution that legal aspects and reuse licenses are established, which gives rise to OERs (Open Educational Resource). The term ''open'' involves an active participation in five activities determined by [11] as the 5Rs: retain, reuse, revise, remix and redistribute.

Based on the contributions of [12], [13] the existing relationships between OER, LO and virtual courses are expressed in Figure 2.

For the description of the accessibility characteristics of the contents published in learning objects, it is necessary to use information description mechanisms based on metadata, which would facilitate the information of a digital resource and its possible requirement based on preferences and needs of the student.

Reference [14] is considered as a reference in metadata frequently used. The accessibility metadata defined by Schema.org are based on IMS AfA v3.0 [15], which responds to the ISO/IEC 24751 standard on individualized adaptability and accessibility in e-learning, education and training [6]. In the case of students with disabilities, the information of a resource is relevant because it facilitates their interaction. Accessibility metadata allows describing the accessibility characteristics of the resource (DRD) [16], as well as the user's preferences and needs (PNP) [17], as shown in Figure 3:

C. ARTIFICIAL INTELLIGENCE: MULTILEVEL

By virtue of the different user requirements, the process of adapting the learning object must be flexible enough, in order to meet the user's diverse requirements. Therefore, our proposal is supported by previous work described in [18]–[20], where alternatives focused on content adaptation at different levels of granularity using techniques based on uncertain reasoning, reuse of learning fragments/objects to create new ones, and multilevel clustering techniques are proposed.

However, our model employs an approach based on artificial intelligence techniques that allow combining different levels of granularity in order to meet users' adaptation requirements. As shown in Figure 4, fundamentally auditory, textual and visual information needs to be adapted according to the users' needs. For this purpose, we propose a level of abstraction of adaptation of each information element, using different artificial intelligence techniques described in the following sections. For example, a user may require that a video that does not have subtitles has them and that a summary can also be presented using texts adapted to easy reading. To do this, the system must first perform automatic speech recognition in order to extract the corresponding textual information. Then the operations and results are combined at two different levels of abstraction, the first one converting the plain text to a text that is easy to read, and from that text the required summary is obtained.

Similarly, for the image-description process, the system extracts all the images as well as the near texts. In this line, the images are analyzed considering four levels that rely on nine CNN (Convolutional Neural Network) for image classification, two CNN + RNN (Recurrent Neural Network) for photos and equations description, and one LSTM NN (Long Short-Term Memory Neural Network) from Tesseract OCR library for text recognition. For the CNN + RNN the system does not need the texts that are near to the images, whereas for the CNN we have implemented an NLP (Natural Language Processing) process that helps describe the images using the near texts.

With this, the user can have as many combinations as he wants, and much more flexible adaptation processes are feasible.

D. RELATED WORK

Some projects have been developed to favor accessibility and adaptability in virtual environments. The shared experiences EU4ALL [9], ESVIAL [21], TILE, AEGIS, ACCESSIBLE [22] OBBA in Brazil [23], to mention a few, point to research and implementation efforts to favor educational inclusion. In parallel, the evaluation of digital learning resources, generates proposals for models and standards to be applied, for which, the accessibility criterion is considered relevant but still does not achieve a consensus of information. Standards such as ISO 9241-11 [6], ISO/IEC 19796-3 [24], ISO/IEC 24751-3 [16], establish guidelines that are related to accessibility; however, the applicability and diffusion is still limited. Methodological proposals focused on the quality of virtual educational resources are based on ISO standards, establishing guidelines for applying ICTs in teaching. Authors such as [21], [25] identify the lack of

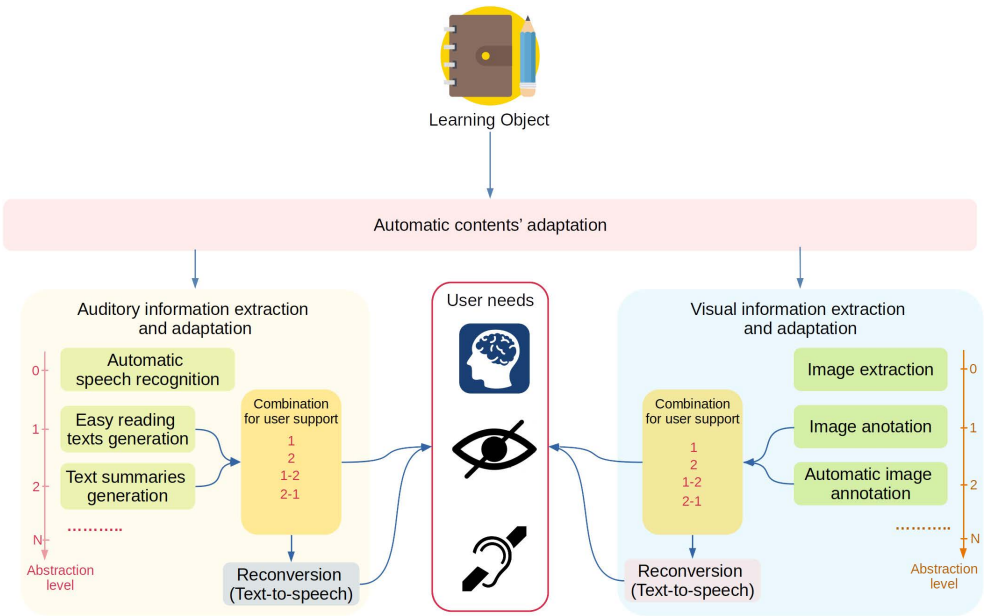

FIGURE 4. Multilevel approach to adaptation of learning objects considering elements of artificial intelligence.

an accessibility methodology with a holistic and adaptive approach.

The collaborative approach from which OERs are born leads to the joint pursuit of pedagogical and technological challenges to achieve an improved reconstruction with quality. [26]–[28]. It is necessary to evidence defined metrics that endorse methodologies [21] and reference international guidelines or instructions related to design for all [29].

The incorporation of intelligent systems could contribute in the evaluation of accessible resources and in the feedback of profiles and personalization from the user experience [30], [31].

The efficient publication of accessibility information would facilitate optimal navigation and search of resources according to student needs and preferences [32], [33].

III. STATISTICAL ANALYSIS OF THE NEEDS OF USERS WITH DISABILITIES

As a previous step to the development of the proposal and the different tools described in this article, it was considered essential to know the needs of real users with different types of disabilities. For this purpose, a pilot study was conducted with 47 volunteers (20 women and 27 men), aged between 17 and 63 years (mean = 27.3, SD = 11.18) who interacted with virtual platforms in both undergraduate and graduate training environments. In order to gain insight into the perceptions of users' needs and requirements, a survey was developed and organized into two sections: one to collect demographic and disability data (9 questions) and another to determine the technological tools they use and the preferences/needs and difficulties they face with respect to the accessibility of virtual educational environments and their resources (36 questions).

TABLE 1. The number of volunteers grouped by gender and disability.

Volunteers(grouped by gender)			Disability
Female	Male	Total	
2	4	6	Deafness (1 woman and 2 men have around 50% of hearing loss)
2	4	6	Deafness but has cochlear implant/audiophones (can hear)
5	7	12	Physical disability
4	4	8	Intellectual/developmental disability
3	1	4	Mental health problems or psycho-social disorders (eg depression, bipolar disorder, schizophrenia, etc.)
3	5	8	Visual impairment (mild, moderate, severe, blindness)
1	2	3	Other disabilities (cerebral palsy or acquired brain damage, diseases of organ systems, etc.)
	Total	47	

After the explanation process provided to the participants, the survey was conducted with the support and guidance of a group of experts in the area of educational inclusion, health, labor inclusion and computer science, in case they had difficulties in understanding the questions or could not interact with the virtual platform. The survey was validated with Cronbach's Alpha test, obtaining a value of 0.94. Table 1 describes the types of disability that these people have, grouped according to their gender. As can be seen, the group of volunteers was intended to represent cases of people who commonly access or have had previous experience in the management of online learning environments or in the use of virtual tools.

In this regard, 5 of the women who participated in this initial study had postgraduate studies, 2 had a bachelor's

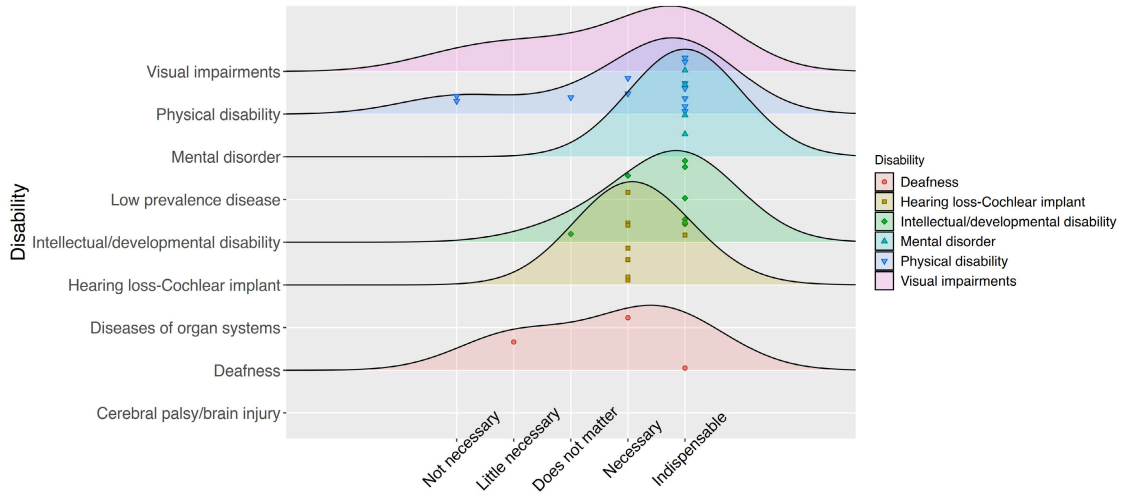

FIGURE 5. Perceptions of surveyed persons with disabilities regarding the criterion "the educational resources must use mostly graphical contents."

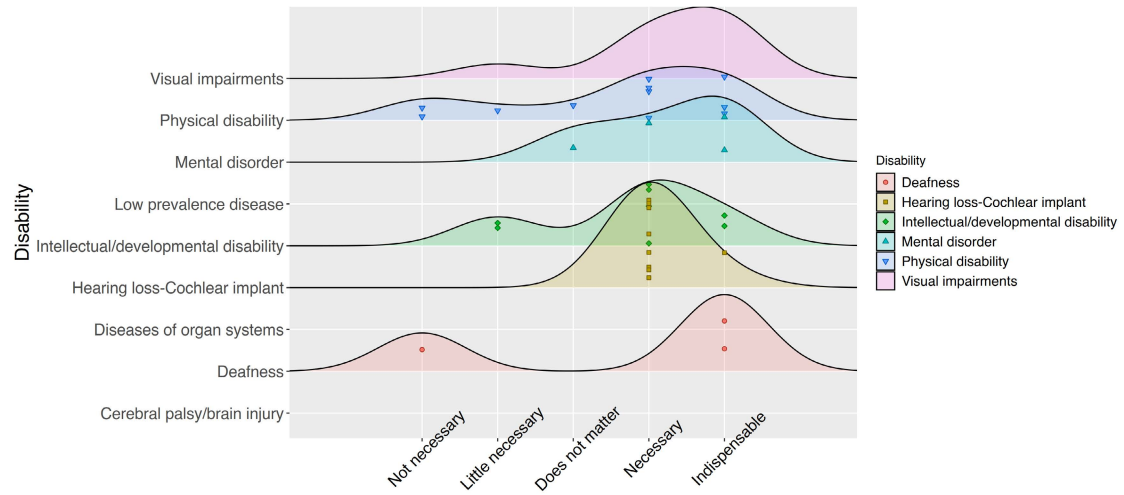

FIGURE 6. Perceptions of surveyed persons with disabilities regarding the criterion "the educational resources must use mostly textual contents."

degree and 13 had a university degree. Among the men, 2 had postgraduate studies, 20 had a university degree and 5 had a bachelor's degree. Regarding employment status, 19 men are not working and 8 are employed in various positions: teaching (3), administrative in a company (2), independent business (1) and operational (2). In the case of women, 11 are unemployed and 9 have the following jobs: teaching (2), independent business (4), management position (1), administrative position (1) and operational position (1).

Figure 5 shows the perception of the volunteers with respect to the possibility of using mostly graphic content in the educational resources uploaded in virtual learning environments. As can be seen, people with visual impairment, deafness or physical disability have different criteria, some consider it necessary, while others do not. However, for people with mental health problems and intellectual/development disabilities, they consider it ''indispensable'' and ''necessary'' to have graphic content.

On the other hand, Figure 6 shows the opinion of the volunteers regarding the criterion that learning objects deployed in virtual educational environments should use mostly textual content. In this aspect, it is observed that most deaf people believe that it is ''indispensable'' that the contents are mainly in textual format. In the case of people with hearing loss who use cochlear implants or hearing aids, they consider it ''necessary''. For people with intellectual/developmental disabilities the criterion varies from ''little indispensable'' to ''indispensable'', with no clear trend. Similarly, for survey participants with health problems, visual impairments and physical disabilities the criteria are scattered, with no clear trend.

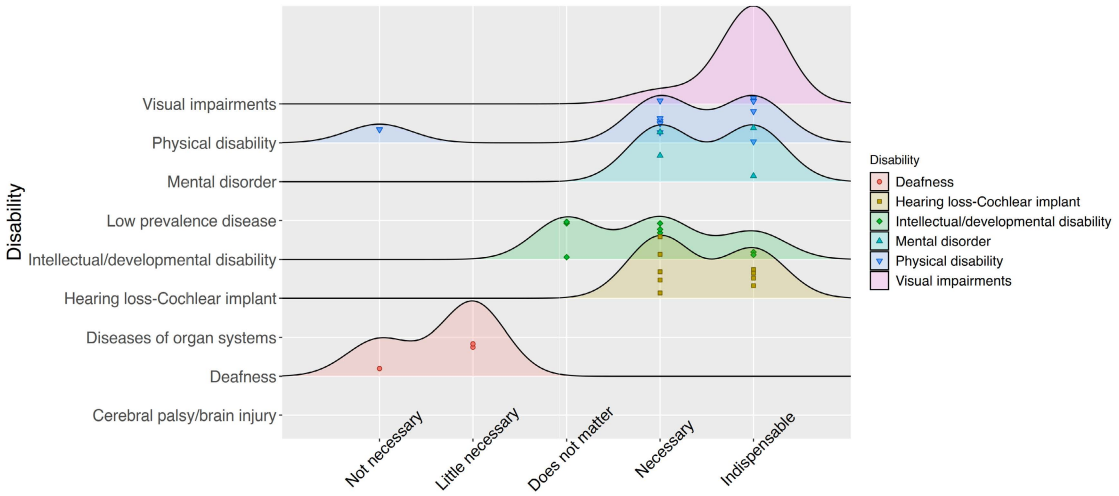

FIGURE 7. Perceptions of surveyed persons with disabilities regarding the criterion "the educational resources must use mostly auditory contents."

Finally, Figure 7 shows that deaf people consider that it is not necessary and very little necessary for learning objects deployed in virtual educational environments to use mostly auditory content. This is very coherent, since this type of resources cannot be used by them at all while using the learning object. In the case of people with hearing loss who use cochlear implants or hearing aids, they consider the criterion to be divided between ''necessary'' and ''indispensable'', since they can access these contents. As for people who are blind, the tendency is completely aligned with the ''indispensable'' option, since auditory content is the main resource they have to access the content of a learning object. For people with intellectual/development disabilities the criteria vary between ''doesn't matter'', ''little indispensable'' and ''indispensable'', with no clear trend.

Similarly, for survey participants with mental disorder and physical disability the criteria are scattered, with no clear trend.

IV. METHODOLOGY

A. SYSTEM ARCHITECTURE

The architecture proposal requires the loading of the learning object, which is usually packaged in SCORM, IMS, Common Cartridge educational format, being its common structure a compressed ZIP file. This is followed by the unpacking of the content and the extraction of its respective tags. Figure 8 shows the general architecture diagram.

1) MULTIMEDIA EDUCATIONAL RESOURCES

The multimedia educational resources layer contains the information extracted from the learning object in terms of textual content, video content, audio content and images. Using artificial intelligence techniques, the content is adapted in its specific modules for learners with different disabilities.

Audio content analysis module: automatic speech recognition for SubRip Subtitle file generation As seen in the statistical analysis conducted with 47 people with various types of disabilities, the audio aspect is a key feature for people with varying degrees of hearing loss. Therefore, it is essential that learning objects containing videos have subtitles in order to meet the needs of this group of people. Therefore, this section describes the module that allows extracting an audio track from a video contained in a learning object and from it obtaining a text file with the audio transcription. Likewise, based on this text file and the audio of the video, the module can also generate a SubRip Subtitle file (SRT).

Figure 9 shows the process carried out by the module for two possible scenarios: a) generation of an SRT file in case the video does not have subtitles and b) comparison of subtitle files created by external tools and SRT files generated by the module. The most important aspects of the stages carried out by the audio analysis module are detailed below.

In the first scenario, the module extracts the audio track from the video using a sampling frequency of 44.1 KHz and stores it in a Waveform Audio File Format (WAV) file (step 1). For this purpose, the open source, cross-platform tool FFmpeg1 is used. The WAV file is then analyzed through Automatic Speech Recognition (ASR) in order to extract the different sentences that make up the explanation given by a narrator or persons intervening in the video (step 3). This process is performed offline using the open source and multiplatform tool VOSK that works on top of the KALDI base tool. While the text file is extracted, the time lapses in which the sentences occur are detected and the corresponding timestamp is added, which makes it possible to create the SRT file itself (step 4). With these three steps the SRT file is incorporated to the video and with this it is possible to have subtitling in case it is required by the users of the system.

As for the second scenario, four more steps are executed than in the previous scenario. In this case, it is important

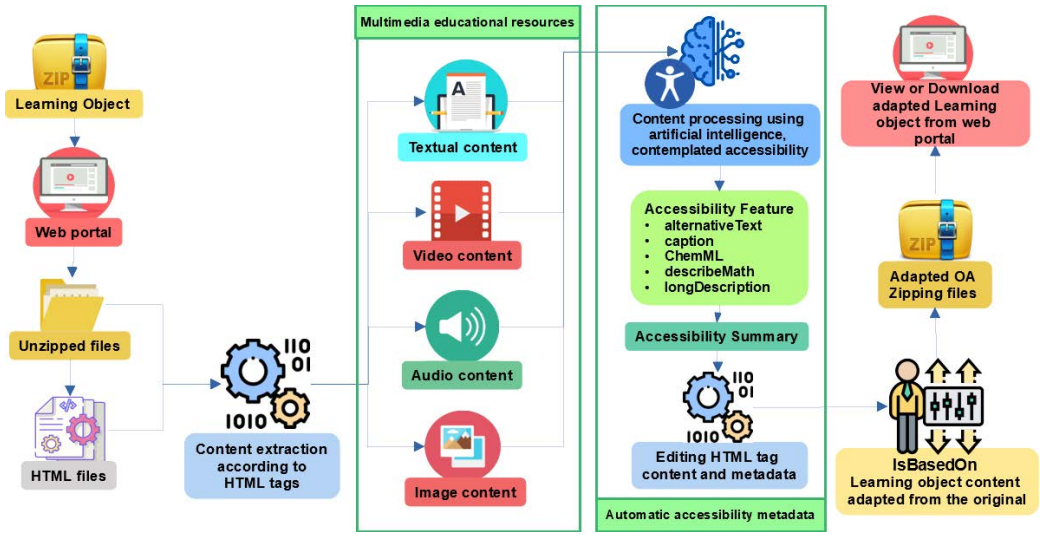

FIGURE 8. The general system architecture organized into modules and layers.

to point out that we start from a video file that already has its own subtitling. Therefore, the first thing to do is to extract the SRT file already included in the video (step 2). Once both SRT files are available (both the one generated with external tools and the one generated by the audio analysis module), the sentences are extracted (removing the timestamps) (step 5). The words of these sentences are converted into word embeddings (for each SRT file) (step 6). To carry out this task we use the neural network that comes pre-trained in the open source tool SpaCY, which is a popular Python library that contains the linguistic data and algorithms needed to process natural language texts [34]. These vector representations are then compared with cosine similarity metrics (Eq. 1) (step 7):

$$sim(SRT, CSTR) \equiv cos(vec(SRT), vec(CSRT)) = \frac{vec(SRT) \cdot vec(CSRT)}{|vec(SRT)| \cdot |vec(CSRT)|} \quad (1)$$

where:

- SRT represents the text (without timestamps) that has been generated by external tools.
- CSRT represents the text (without timestamps) produced by the audio analysis module.
- The *vec*() function is the one that allows to obtain the word embedding from a given sentence.

Figure 9 shows the different steps performed by the audio analysis module considering two scenarios: generation of SRT files for videos without subtitles, and comparison of the quality of subtitles generated versus those generated by external tools. With this, we can determine how effective is the result generated by the audio analysis module, as long as we start from a given gold standard, i.e., having an annotated corpus where we know exactly which words and sentences should be recognized by the tool. In our case, we used YouTube's automatic subtitling tool, as it is the one commonly used for the generation of educational content of various kinds. However, we should not lose sight of the fact that no tool is able to perform subtitling with 100% accuracy due to various aspects (noise, incorrect pronunciation of the speaker, idioms/localisms, etc.).

Image and textual content: In the extraction of the images present in the object, the <figcaption>, <img> tags and the information of the TAGs closest to the image are analyzed from the different HTML files: <h>, <p>, etc. The identified images go through different neural networks to generate information according to their content. The processing ends when editing the HTML file by adding information to the alternative text, which will support a correct labeling later. See Figure 10.

The proposal presented with its different multilevel deep learning networks, represent an adequate identification of description in 49% of images found with their different types or areas. The addition of several layers of deep learning considerably improves the classification of images, due to the number of images needed for training in specific classes and their characteristics.

For image classification, convolutional networks are used by Transfer learning described in [35]. For each category, it trained with more than 4k images. To generate a broad or complementary description of the classified images, natural language processing is used, improving the description and validating it semantically.

In order to improve the description of the images, natural language processing is used, which uses the information obtained from the , <p>, <spam> or other tags with textual information closer to the image until reaching a <h1>-<h6> tag or another image. This description must comply with a semantic analysis that validates it. In case of being validated, this description is complemented to the result of the classification of the multilevel neural networks

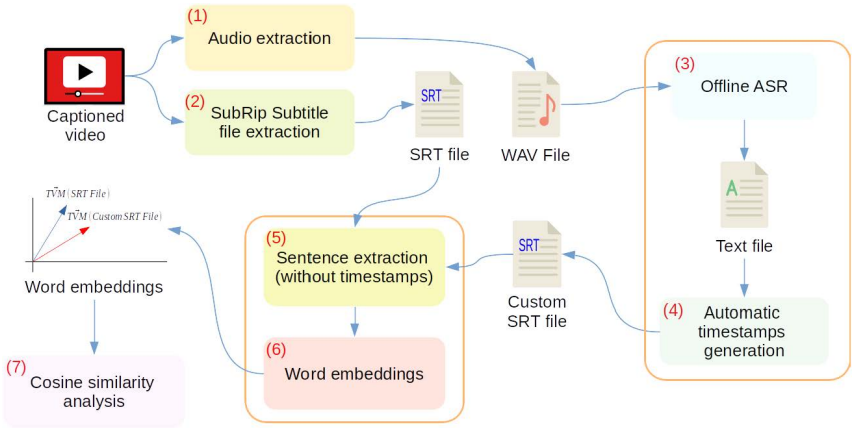

FIGURE 9. Audio analysis module.

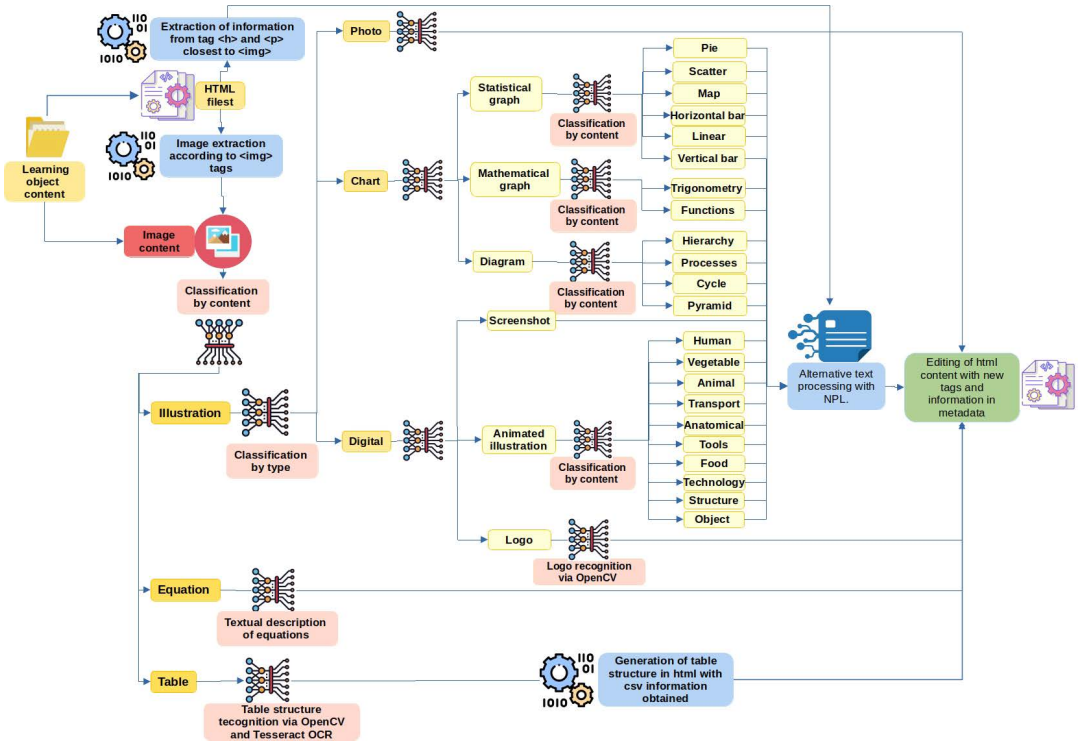

FIGURE 10. Multilevel deep learning proposed for classification and description of images.

processing (process in development). In case of not having a description of the semantic analysis verified by NLP, the closest title or subtitle prior to the image is used, complemented with the result of the classification of the multilevel Deep learning networks processing.

In the case of photographs, the neural network architecture is based on [36] and equations based on [37]. This architecture is based on the combination of CNN-RNN. CNNs preserves the spatial information and RNNs handles the sequential data. In these cases, use was made of LSTMs which are a modified version of recurrent neural networks. In the description of the photographs, the MS COCO dataset database was used, which has 180k training images with their respective annotations; as an addition to this database, 2k images with their description referring to educational topics were included. In the case of equations description, we made use of a database of 400k images with their annotations, this database was generated according to [37], as an aggregate we expanded characters and equations.

To generate a table in HTML sentences and tags, text recognition with Tesseract OCR engine is employed.

For logo recognition, the database of logos of brands from all over the world [38] are used because each logo has its own name and in most databases these are represented by the

```
<meta itemprop="accessMode" content="auditory">
<meta itemprop="accessMode" content="textual">
<meta itemprop="accessMode" content="visual">
<meta itemprop="accessibilityFeature" content="caption">
<meta itemprop="accessibilityFeature" content="alternativeText">
<meta itemprop="accessibilityFeature" content="synchronizedAudioText">
<meta itemprop="accessibilityFeature" content="describedMath">
<meta itemprop="accessibilityFeature" content="MathML">
<meta itemprop="accessibilityFeature" content="ChemML">
<meta itemprop="accessibilityFeature" content="audioDescription">
<meta itemprop="accessibilityFeature" content="transcript">
<meta itemprop="accessibilityFeature" content="ttsMarkup">
```

FIGURE 11. Automatic accessibility metadata.

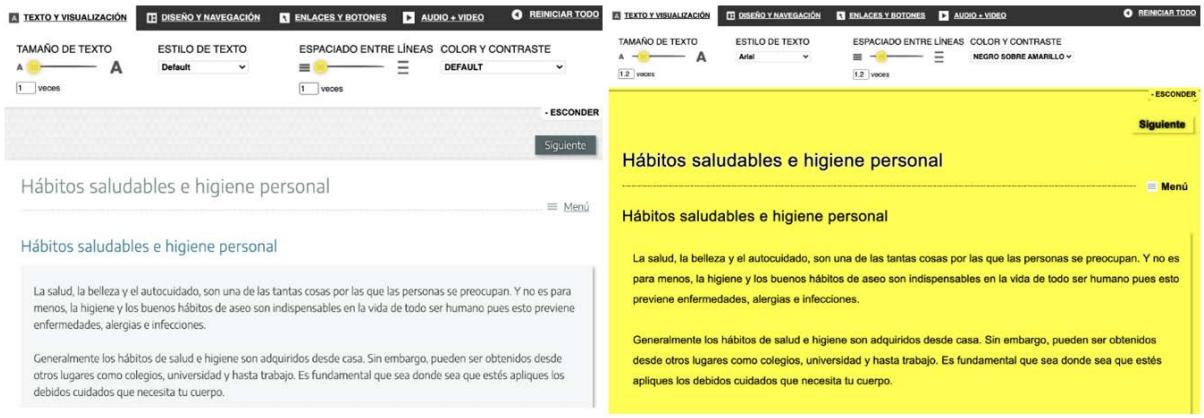

FIGURE 12. Accessible interface configuration. The screen capture of the left side shows the options to modify the user's preferences, whereas the image on the right side shows the result of applying high contrast on the learning object.

name of the company in general. The database has the largest collection of logos worldwide exceeding 300K.

2) MULTIMEDIA EDUCATIONAL RESOURCES

With the automatic identification and adaptation of the learning object, the appropriate labeling is generated considering the Schema.org guidelines and accessibility metadata as shown in Figure 11.

Additionally, the customization of the learning object interface is considered using the framework of the Fluid Infusion project [39] that combines JavaScript, CSS, HTML and user-centered design to support inclusive design on the web. This framework integrates at the top of the web page (Figure 12) an interface configuration palette with which the following can be adapted according to the user's needs or preferences:

- Text and display: Text size, text style, line spacing, color and contrast.
- Layout and navigation: Display the table of contents.
- Links and buttons: Emphasize links and magnify entries.
- Audio and videos: Display subtitles whenever possible, display transcripts whenever possible, default volume and default language.

With this it is possible to identify the automatic incorporation of the following accessibility metadata:

- accessibilityFeature: displayTransformability/ background-color
- accessibilityFeature: displayTransformability/ font-family
- accessibilityFeature: displayTransformability/font-size
- accessibilityFeature: displayTransformability/color
- accessibilityFeature: displayTransformability/ word-spacing
- accessibilityFeature: displayTransformability/ line-height
- accessibilityFeature: captions
- accessibilityFeature: synchronizedAudioText
- accessibilityFeature: highContrastDisplay
- accessibilityFeature:transcript
- accessibilityFeature: structuralNavigation
- accessibilityFeature:readingOrder
- accessibilityFeature: tableOfContents
- accessibilityFeature: index
- accessibilityFeature: audioDescription

V. EXPERIMENTATION AND RESULTS

In order to determine the accuracy of the audio analysis module, a process was carried out in which hundreds of videos were collected from the YouTube platform and 60 videos were selected from three different categories: chemistry, programming and mathematics. The videos were

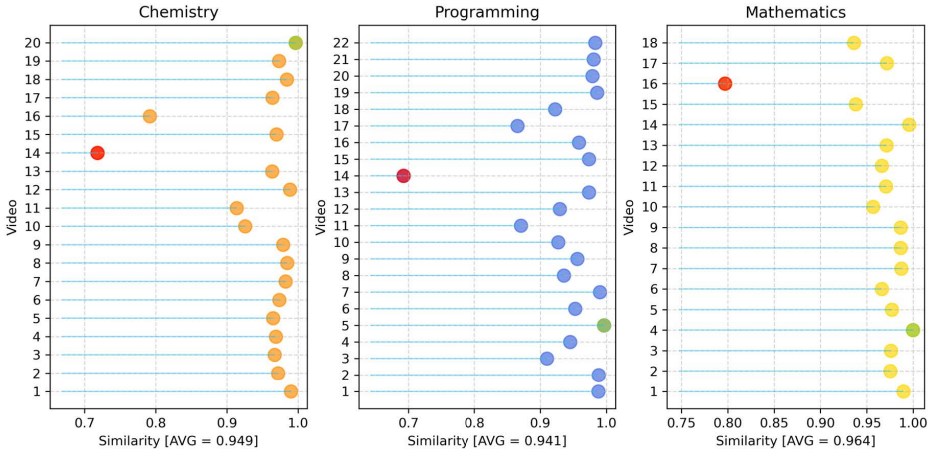

FIGURE 13. Similarity results obtained between the subtitles generated by external tools (YouTube®) and the audio analysis module.

reviewed manually in order to determine if the subtitling corresponded to the audio of the video.

Once this aspect was verified, we proceeded to use the audio analysis module based on the second scenario, i.e., comparing the similarity between the text already in the video and the text generated by the module.

As can be seen in Figure 13, the results are very positive, since on average the values for the three categories are 0.949, 0.941 and 0.964, respectively. The subtitles with lower similarity exceeded the value of 0.7. With this, we can determine that the quality of the texts generated by the audio module are comparable to those that can be achieved with external tools.

In relation to the description of images in learning objects, an analysis was made on the integration of the description or captioning of images in 15 learning objects with a total of 192 images. It was found that most of the images do not have any description in any of the forms normally used, identifying that the description is in the tag <alt>, <figcaption> or in any tag either ,<p>, or other tag in which it presents a prefix (Figure, Fig, Image, Graphic). Table 2 shows the percentage of the use of the tags for the description of the images in its different ways, taking into account that the ''Yes'' represents a correct description, which provides relevant information for the understanding, in case it is not complete or relevant a ''No'' has been imposed.

Considering that a good practice for image description is to add it in <figcaption> and <alt> tags, the proposed tool to find a description in other tags or TAGs removes them and generates the description in <figcaption> and <alt> so that it can be read correctly by a screen reader.

Based on this analysis, in order to generate a description for 49% of the images, image processing using Artificial Intelligence is used, whose main objective is to generate information related to the image so that a user can know the content of the image, which may not be displayed in the browser or the user cannot perceive it because he/she has special education needs related to a visual disability.

TABLE 2. Results of the analysis carried out in 192 images from 15 learning objects. Most of images do not have any description such as <alt>, <figcaption> or other tags.

<figcaption>	other tags	<alt>	Images	Percentage (%)
No	No	No	94	48.96
No	No	Yes	14	7.29
No	Yes	No	36	18.75
No	Yes	Yes	26	13.54
Yes	No	No	0	0
Yes	No	Yes	22	11.46
Yes	Yes	No	0	0
Yes	Yes	Yes	0	0
		Total	**192**	**100**

This generated information will be present in the <figcaption> and <alt> tags, generating the alternativeText metadata or in specific cases the image will be converted into HTML content that can be interpreted in a browser and can be read by a screen reader.

The 94 images that do not have any description were classified. In Figure 14 we can see the results obtained from the classification using the ROC (Receiver Operating Characteristic) curve [40], which is a graphical representation of the ratio or proportion of true positives (TPR = True Positive Ratio) versus the ratio or proportion of false positives (FPR = False Positive Ratio), also according to the variation of the discrimination threshold (value at which we decide that a case is a positive), with an area under the curve of 0.65 in its lowest classification and an area of 0.98 in the highest classification.

In turn in Figure 15 we can see the result of the generation of the description of the subsequent images of the different classifications.

A. RECOGNITION OF INFORMATION PRESENT IN IMAGES OF TABLES

Only four images that represent tables were properly detected in all learning objects analyzed. In the same line, the HTML

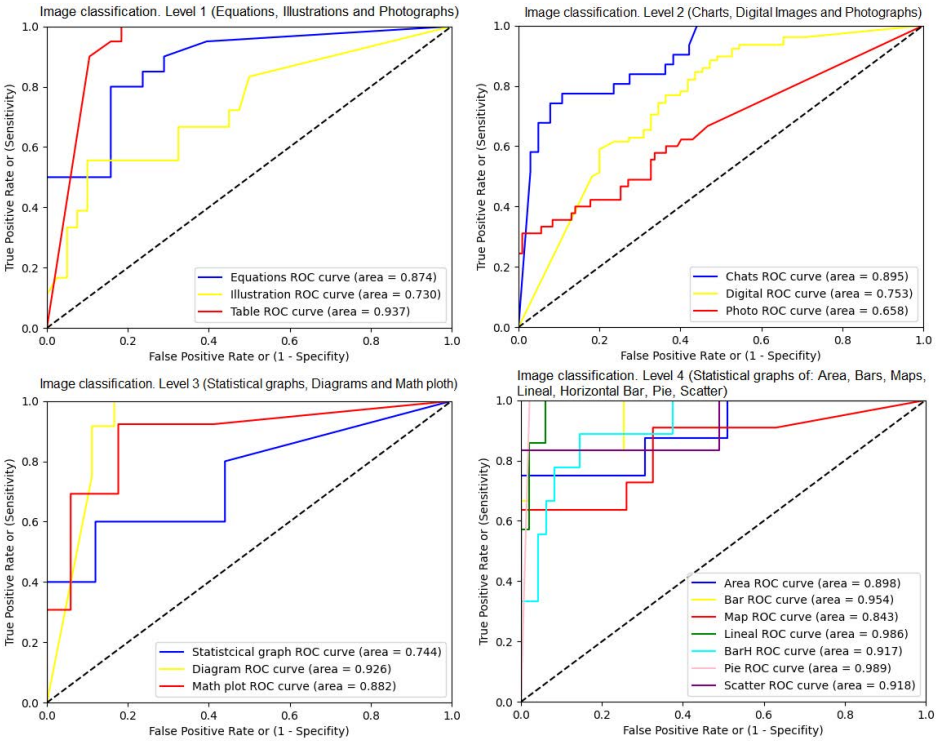

FIGURE 14. ROC curves for image classification according to the four levels defined.

code was successfully generated for these tables. These tables had a basic style without colors and defined cell lines.

To determine if the tool works properly, one of the tables was tested with different formats. As shown in Figure 15, a table that does not have a correctly defined grid, such as the external frames and the title and the color of the letters is soft, gives results with errors. In this case only the table was recognized and assembled in HTML with the cells that can be distinguished. In the following case, a table with a white grid was tested, which caused the cells not to be recognized. At the same time, the white text and the dark outline did not allow any text in the image to be recognized.

B. LOGO RECOGNITION

In the learning objects analyzed, 15 logos were found, most of which (12/15) were correctly recognized, with particular cases of regional or local logos that are not in the database. See Figure 15.

VI. LIMITATIONS

This research presented limitations during the process and in its search to answer the interaction questions from the experience of students with disabilities. The selection of the sample is limited. However, by obtaining a coefficient of 0.94 in Crombach's alpha, an optimal level of reliability is determined, thus identifying a reduction of bias. The automation of images responds to a diversity of categories with databases that are out of context, considering also that many images respond to mixed contents with texts in different languages and in many cases, the quality is not adequate for an optimal comparison; however, the bias was reduced by choosing a set of databases that cover the main disciplinary fields.

Another limitation is the selection of audios, but even so, it is considered that the evaluation process offers us a good overview of the scalable feeding of auditory information, identifying several relationships.

VII. DISCUSSIONS AND RECOMMENDATIONS

The objective of this work was to determine the barriers frequently detected in accessibility, from the own experience of students with disabilities in virtual environments. The results showed a lack of implementation of accessibility regulations in educational resources and learning objects, with special emphasis on images, video and their corresponding audio. While standards have been planned throughout history, the guidelines for their use are still subject to subjective criteria that depend on the design and implementation of a digital educational resource and student feedback. Adequate processes to meet reasonable accessibility of images and audios require automated tools that support the teacher to generate greater impact on applicability. Ensuring that a product complies with accessibility features strengthens the identification of metadata according to the preferences and needs of students with disabilities, as well as the satisfactory or not results of their teaching-learning process. Case reports

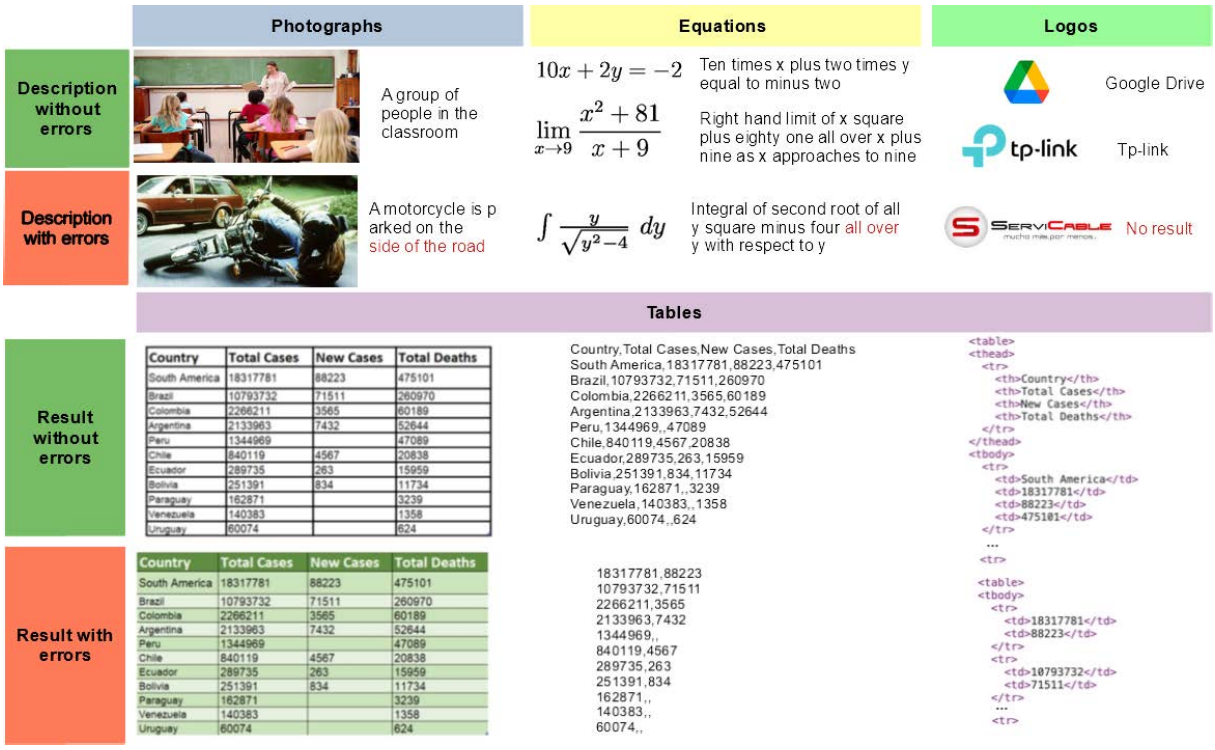

FIGURE 15. Results reached by the system with the automatic description process for images, photos, tables, and equations from learning objects.

are established with a limited number of subjects. The studies focus essentially on local experiences and rarely evaluate the positive effects of accessibility in interaction with learning objects in virtual environments. As a result of this research, we propose the development of an automatic adaptation tool to strengthen the accessibility and adaptability of OER considering standards and metadata.

A. RECOMMENDATION AND FUTURE DIRECTIONS

Through the findings and research perspectives on the various proposed solutions to improve the field of accessibility and adaptability in OER, it is relevant to explore the efforts generated to adapt resources and the effort required by each teacher, whether or not they have computer and accessibility knowledge. Although [9], [41], [42] apply numerous practices to incorporate accessibility, it is still complex to respond to automatic tools that consider accessibility guidelines and metadata established for the effect.

The advantages of a proper implementation of metadata publication is still not a general domain knowledge, as concluded by several authors [25], [43]. The effective applicability of accessibility metadata, could trigger a breakthrough in relation to the problem of finding accessible educational resources, effectively validated, and that respond to the variability in a student's learning, given their needs and preferences, considering that the efforts generated to create accessible OER enriches the universality of education.

Studies conducting experiments to develop recommender tools [31], [44], [45] that favor the information of accessible educational resources, as well as the possibility of feeding from diverse student profiles, seek to compare the effectiveness and degree of satisfaction of a student when being able to interact with appropriate resources. The needs and preferences of a student should be in sync with resources that meet those requirements, and education undoubtedly generates valuable educational material that could favor repositories and enrich the educational process that is strengthened in a virtual environment by not knowing borders and having an open availability.

Based on the research carried out, it is established that there are no automatic tools that favor the adaptability and accessibility of an OER considering the correct implementation of its metadata. It is considered that it is necessary to generate new metadata that respond to the guidelines determined by the Universal Design for Learning [46], so we propose as future work, to explore and investigate the strengths and weaknesses of OERs and the implementation of tools that facilitate the proper incorporation of their metadata from the students' experience and their variability in learning. Accessibility in virtual education is an issue that must be socialized, so it is emerging to contribute with OER that responds to the functional diversity of learning.

B. CONCLUSION

The objective of our study was to contribute to lay the foundations for an automatic adaptation of images and audios that meet accessibility standards and correct labeling through their metadata. Despite the limitations of this research, since

it is based on scientific literature data, we consider that the bias was reduced by covering the identification of the main databases with more than 600k in their different images and audios.

Four main conclusions can be formulated. First, there is a paucity of applicability of accessibility metadata in OER. Moreover, available studies tend to focus more on design recommendations than on their effective adaptation for optimal interaction with students with disabilities. Second, the use of accessibility standards and metadata is subjective, in several cases responding to evaluative models that, although they consider accessibility as an evaluative metric, it is inconsistent to arrive at a common implementation process. Third, there is a lack of references that establish a significant sample of students with disabilities, their follow-up, monitoring and learning process, which requires more time to obtain reliable data.

In summary, this study reveals an automatic tool proposal that facilitates the implementation of adaptability and accessibility considering its metadata, information that can help other researchers and developers to incorporate the subject matter in the modeling of accessible resources considering the learner's needs and preferences. 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 contributions throughout history have generated standards and regulations that have motivated research, there is still a lack of automatic tools that favor ideal implementation. The information from quantitative, qualitative or mixed studies is insufficient to determine the impact on students with disabilities, so there is inconclusive data on the applicability of educational resources and search repositories.

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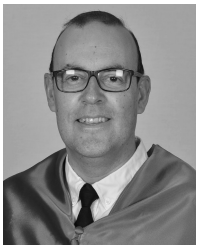

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2.4 Artículo IV: RALO: Accessible Learning Objects Assessment Ecosystem based on metadata analysis, inter-rater agreement, and Borda voting schemes

El artículo presenta una propuesta de metodología para la evaluación de accesibilidad de objetos de aprendizaje mediante metadatos La creación, gestión y evaluación de OAs accesibles, logran sincronía con recursos que pueden ser reutilizados. El análisis de casos de estudio nos ubica en el impacto de evaluar OAs accesibles a través de metadatos. Se establece una necesidad importante en la generación de herramientas y técnicas que promuevan su desarrollo y fortalezcan su evaluación e impacto. Se considera que es necesario establecer directrices de accesibilidad que guíen en la eliminación de barreras, por lo que es necesario mantener una exploración e investigación activa de las fortalezas y debilidades de los recursos educativos accesibles, compatibilidad con tecnología de asistencia y la implementación y socialización de herramientas que favorezcan las capacidades de evaluación de OAs accesibles para generar una cultura de diseño inclusivo lo cual contribuye a una óptima evaluación de calidad .

2.4.1 Contribución

Esta investigación se alimenta de los diversos modelos, estándares y herramientas empleadas para la aplicación de OAs accesibles, y propone un ecosistema que considera la creación de herramientas que sustentan el modelo de evaluación de accesibilidad y adaptabilidad fundamentado en las necesidades y preferencias del estudiante. Se establece la necesidad de una publicación de información de accesibilidad idónea para una efectiva respuesta de búsqueda personalizada acorde a requerimientos de interacción de un recurso educativo. El objetivo del presente documento es contribuir a establecer métricas evaluativas de OAs accesibles acordes a sus metadatos de accesibilidad y adaptabilidad para evaluar un objeto de aprendizaje, identificando características del recurso (DRD) en sus recursos digitales visuales, textuales, auditivos y su nivel de interactividad, así como también su impacto en el aprendizaje acorde a las necesidades y preferencias (PNP) establecidas en las redes de expresión, representación y motivación de DUA. La propuesta del modelo identifica su potencialidad y experimenta que es

necesario el uso frecuente y socialización de los actuales metadatos de accesibilidad en plataformas y herramientas de creación de OAs, esto lograría la identificación o creación de propuestas en base a modelos evaluativos específicos aplicados en un modelo educativo. Es necesario considerar que la medición de impacto es un proceso de monitoreo y seguimiento continuo afianzado en el desarrollo sostenible de una cultura de inclusión educativa avalado en la sensibilización y conocimiento de potencialidades y no limitaciones.

2.4.2 Artículo

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RESEARCH ARTICLE

RALO: Accessible Learning Objects Assessment Ecosystem Based on Metadata Analysis, Inter-Rater Agreement, and Borda Voting Schemes

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ABSTRACT The increasing number of people are living with disability in the World and their access to formal education is considered a challenge for the development of the online education and educational resources. This problem is considered one of the 17 sustainable development goals that are focused on inclusive and equitable quality education. Nevertheless, the existing proposals for mainstream accessibility in virtual education are still complex to apply. However, the models, standards, and good practices to contribute to the virtual educational process and the design of learning for all are identified. For these reasons, in this paper, we describe an accessibility evaluation proposal based on 4 interaction domains: user analysis and interaction, intelligent systems, knowledge databases, and evaluation. In the same way, we describe a set of tools that constitute a Repository of Accessible Learning Objects (RALO) from the perspective of accessibility and adaptability metadata. In this line, the knowledge database follows the regulation and educational models focused on the students with disabilities needs and preferences from the conception of universal design. The validation of the proposal is based on the interaction study and analysis of regular and disabled students and teachers who developed the Learning Objects (LO). To determine whether there was consensus among the teacher's scores, we used Kendall's Coefficient of Concordance W.

INDEX TERMS Learning object, distance learning, accessibility, evaluation, metadata.

I. INTRODUCTION

The existence of various models, standards and tools used for the application of accessibility in digital educational resources considering metadata, is still considered a ''technical or computer issue'' and is not committed to the diversity in learning of all students and even more in those who have disabilities. The diverse educational experiences of students with disabilities help to generate resources for a wider universe of needs and requirements. The correct labeling of accessibility metadata in learning objects has a great influence on the effective response of personalized search engines according to interaction requirements that facilitate learning. Although contributions throughout history have generated standards and regulations that have motivated research on the subject, there is a lack of suitable implementation and frequent use for their application, especially in developing countries. The information from quantitative, qualitative or mixed studies

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related to accessible learning objects is insufficient to determine the impact on students with disabilities at a general level, so an evaluation and feedback process is required both for those who generate resources and for those who consume them; this involves and commits all actors within an educational project that supports a virtual environment without barriers. Considering that accessibility and adaptability achieve a synergy in the production and evaluation of a learning object (LO), a referential framework is established to support the proposed analysis from the perspective of the student and his or her adaptability requirements and from the perspective of the teacher or creator and manager of an accessible LO. This document presents the proposal of an ecosystem for the evaluation of learning objects through the development of a feedback repository of tools that automate processes of metadata use and considerations of accessibility experts, is organized as follows: Section II presents the background and the standards and models considered for the proposal. Section III provides details of the proposed architecture for the development of the accessibility and adaptability ecosystem in accessible learning objects. Section IV presents the analysis of results. Section V presents the limitations encountered, and Section VI concludes with the discussion of findings and recommendations.

II. BACKGROUND

The existing relationship between the different digital educational resources that make up a virtual environment and their interaction with the user, demands the establishment of characteristics that allow to analyze the accessibility and adaptability in each of them. Accessibility in a virtual educational resource on the web is based on the existing worldwide standards from the creators of the W3C and its guidelines through the WAI and WCAG, processes that have been endorsed and adopted by several legislations in various countries. Although not all standards are completely correlated with the experience in a virtual educational environment, the fundamental bases of accessibility respond mostly to the application and compliance with guidelines that establish interaction compliance for people with disabilities. Web accessibility is led by the World Wide Web Consortium (W3C) which is the primary source for establishing technical standards to ensure accessibility, [1] including:

- WAI ARIA: Defines technologies to make dynamic web applications more accessible.
- WCAG: Establishes guidelines for creating accessible websites.
- ATAG: Establishes guidelines for developing authoring tools with accessibility in mind.
- UAAG: Establishes guidelines for developers of browsers, players, etc. considering accessibility.

In relation to accessibility in virtual learning environments, the guidelines are given by

- IMS AfA: Global learning consortium leading standards for access for all [2].

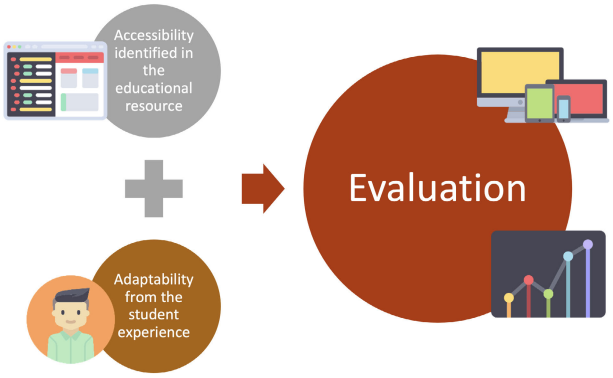

FIGURE 1. General structure of evaluation of LO accessible that involves the analysis of accessibility from the digital educational resource itself and the analysis of adaptability from the user experience.

- ISO/IEC 24751 Adaptability and individualized accessibility in e-learning, education and training, based on IMS AfA [3].

When developing accessible digital material it is necessary to consider visual, auditory and textual resources and their different levels of interaction. Reference [4] considers that accessibility is not only framed in technology and its interaction, it also requires feedback from the design of learning experiences for all, considering not only technology and pedagogy, but also ethics.

Figure 1 shows a general structure of the components that are necessary in an accessibility and adaptability evaluation considering the guidelines proposed by [2] and [3]

A. REGULATIONS RELATED TO ACCESSIBLE EDUCATIONAL RESOURCES

ISO 40500: The ISO 40500 Web Content Accessibility Standard was published in 2012, with which several countries were able to adopt it as legislation, since WCAG 2.0 was a proposal from a private organization, which made its implementation difficult. In 2018 WCAG 2.1 was published, which has not yet been approved as an ISO standard, but it is the reference recommendation in legislation at present [1]. Other international standards such as the latest version of the European standard EN 301549 have already adopted WCAG 2.1 as a base [5]. Since 2020 this standard is mandatory for all websites of public bodies in the countries of the European Union, including those of educational institutions and their virtual campuses [6].

Virtual environments usually refer to web content. Therefore, compliance with the WCAG and its guidelines are clearly identified.

Based on the WCAG compliance criteria it is possible to detect levels and requirements for content creators, each of them correlated with the educational resources mostly used in a learning object.

ISO 24751: The ISO 24751 standard, on accessibility and adaptability for e-learning, education and training, provides information on accessibility metadata on both the resource

(DRD) and the needs and preferences of users (PNP), through an information model that describes the needs and preferences of learners or users when accessing the digital resource or service; where in addition the conformity criteria depend on the role played by the technology according to the different requirements for educational presentation applications and alternative access systems [7].

ISO 24751 is based on the first versions of the Access For All (AfA) recommendation of the IMS Global Learning Consortium [8], and is made up of 3 parts:

- ISO 24751-1 Information technologies. Individualized adaptability and accessibility in e-learning, education and training. Part 1: Framework and reference model [3].
- ISO 24751-2 Information Technologies. Individualized adaptability and accessibility in e-learning, education and training. Part 2: Needs and preferences for the digital provision of ''access for all'' [9]
- ISO 24751-3 Information Technologies. Individualized adaptability and accessibility in e-learning, education and training. Part 3: Description of digital resource ''access for all'' [10]

B. MODELS RELATED TO ADAPTABLE EDUCATIONAL RESOURCES

UDL: Universal Design for Learning, represents the methodological efforts used by the current of universal learning design, understanding the challenge that means the diversity of learning for students and potentiates the construction of flexible materials, techniques and strategies oriented to a greater number of users. It is considered as a teaching model that provides equal learning opportunities for all students. It contains three principles: multiple means of representation, multiple forms of participation strategies and multiple means of expression. These principles of educational technologies allow maximizing the learning of all students using different teaching methods that identify barriers in a timely manner [11].

UDL constitutes a learning reference for students with greater flexibility, technique and strategies, providing multiple means of its 3 principles, which provide feedback on the user's experience. Its principles, or also called networks, are classified into:

- **Representation:** Covers the perception of the information in different formats such as text, also if it includes support elements for users such as audio descriptions, and at the same time if it allows a more developed understanding of the information such as complementary documents or an accessible guide to the information of the resource:
  - Presents information in different formats (perception)
  - Uses support elements to decode information
  - Provides options for understanding
- **Expression:** It considers user interaction and the use of technical aids if necessary, as well as group or individual activities, and finally the ability to provide tools to facilitate understanding, such as tutorials.
  - Allows multiple means of interacting with the material
  - The response pattern in the activities (expression and communication) is varied.
  - Facilitates the development of executive functions.
- **Motivation:** Covers the way in which a learning object can capture the interest of a user and the different ways to arouse their curiosity, challenges or challenges; in addition to considering whether it provides elements of reward and incentives that support the effort and persistence of users, based on evaluation instruments such as questionnaires for self-evaluation or co-evaluation.
  - Provides options to capture interest
  - Provides options for sustaining effort and persistence
  - Provides options for self-regulation

LRMI: Learning Resource Metadata Initiative. Its objective is to describe educational resources by adding specific properties (metadata) so that they can be easily located through search engines and services. The specifications are based on the vocabulary offered by Schema.org and other standards.

With support from AEP (Association of Educational Publishers), CC (Creative Commons), Division 501, Bill & Melinda Gates, and the William and Flora Hewlett Foundation, LRMI has developed a metadata framework for tagging learning resources on the web. The LRMI 1.1 schema was adopted by Schema.org in 2013, which makes it viable for resources, through their LRMI metadata, to be recognized by major search engines.

AFA: IMS Access for All (AfA) v3.0 [8] was created with the aim of simplifying the ISO/IEC 24751 standard [9], [10] due to the difficulties encountered at the time of putting it into practice. Both, standard and specification in its version 3.0, cover the whole process from the reading of the user's needs to the search mechanism necessary to find the learning object that satisfies those needs or preferences.

It consists of two data models to describe accessibility [8]:

- Personal Needs and Preferences (PNP): Model for describing users' needs and preferences for accessing and interacting with digital resources.
- Digital Resource Description (DRD): Accessibility metadata description model for digital learning resources.

Schema.org: It is currently the most widely used vocabulary in the structured data community for Internet search engine optimization. To define accessibility metadata in Schema.org it is necessary to focus on the different types of web content that can be classified by metadata schema [12]. The ''CreativeWork'' category includes books, movies, photographs, videos, etc. The types can in turn have subtypes, for example, ''CreativeWork'' has the type ''MediaObject'' and this in turn ''VideoObject'', among others.

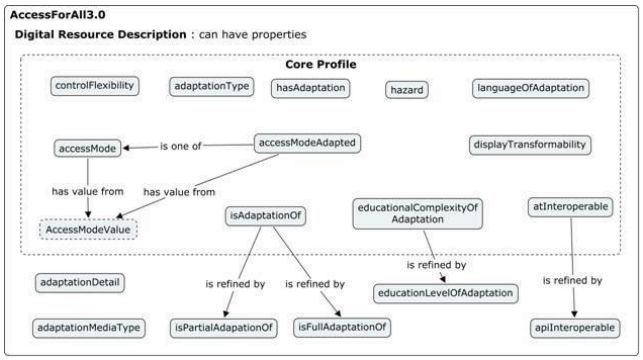

FIGURE 2. AfA 3.0 Digital Resource Description - DRD [13].

The accessibility metadata defined by Schema.org are based on those specified for the IMS AfA v3.0 DRDs, with a significant subset of these being selected. Each of these metadata may have a possible value that is defined in the specification. In this way it is possible to determine the accessibility characteristics of any digital resource published on the web.

C. ACCESIBILITY METADATA

The metadata of an LO responds to valuable information that efficiently determines a process of search, reuse and feedback on features that support assessment and interaction based on the preferences and needs of the learner and their virtual educational experience.

The AfA DRD specification (Figure 2) defines the accessibility metadata of a resource that is necessary for the search and use of the learning resource according to each user.

The way of working with accessible learning objects requires the creation of original and adapted learning objects. An original resource corresponds to an initial resource, while an adapted resource presents the same educational information as the initial or original resource, but other characteristics change, such as the sensory form of access to the resource, the language, etc.

The original resources can have any number of adaptations, which can be total or partial, that is, they are either adaptations of the entire educational content or only part of it.

Metadata can support adequate information on original resources, such as: access mode, accessibility features (subtitle, sign language), interaction features (keyboard, mouse, voice) and possible accessibility descriptions of certain programs.

The AfA PNP specification (Figure 3) is intended to enable the definition of learners' personal preferences and needs (or those due to disabled environments). PNPs are used in combination with the AfA DRD specification to deliver digital resources that meet a user's needs and/or preferences.

The principles for accessibility in e-learning focus on providing customization options based on user preferences, facilitating content equivalents, compatibility with technical aids and full keyboard and mouse access, providing context and orientation information and others associated with following

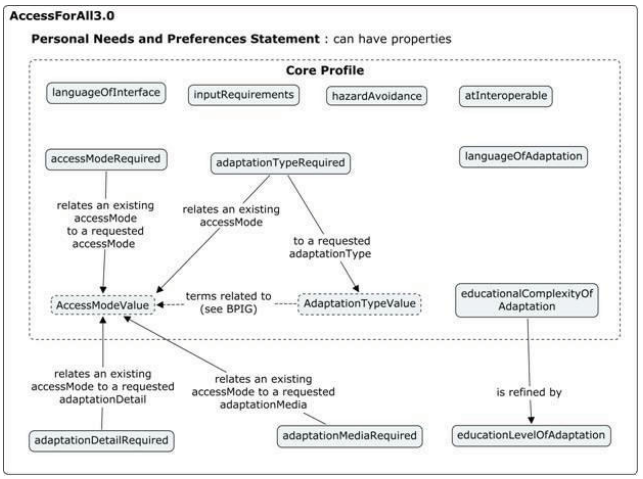

FIGURE 3. AfA3.0 Personal Needs and Preferences - PNP [8].

specifications of guidelines and/or standards of governing bodies in the field such as IMS.

III. REGULATIONS AND MODELS

For the proposal of accessibility metadata that contribute to an evaluation, the criteria for content creators were taken as reference [13] and the identification based on the types of digital educational resources analyzed in WCAG with emphasis on the creation, identification and reuse of learning objects. The analysis is correlated with Schema.org metadata for being the most applicable.

A. DRD - ACCESSIBILITY IN LEARNING OBJECTS

With the background and efforts of standards such as [9] and [14], in DRD, as well as standards such as [1] and [15],), in accessibility identifies 4 groups of resources commonly used in the development of learning objects in virtual environments, these are:

1) VISUAL DIGITAL RESOURCES

7 criteria directly related to visual digital resources established in WCAG and their relationship with Schema.org metadata specified in the WCAG are analyzed in Table 1.

2) AUDITORY DIGITAL RESOURCES

11 criteria directly related to digital audio resources established in WCAG are analyzed and their relationship with Schema.org metadata specified in Table 2

3) DIGITAL TEXTUAL RESOURCES

19 criteria directly related to textual digital resources established in WCAG and their relation to Schema.org metadata specified in the WCAG are analyzed in Table 3

4) LEVEL OF INTERACTIVITY

We analyze 6 criteria directly related to the level of interactivity established in WCAG and its relationship with Schema.org metadata specified in Table 4

TABLE 1. Correlation of accessibility metadata with auditory digital resources.

Criteria WCAG	Level	Description	Metadata and identified value
1.1.1	A	non-text content	accessibilityFeature: alternativeText
1.4.5	AA	text images	accessibilityFeature: long description y accessibilityFeature: alternative text
1.4.1	A	use of color	accessMode: colorDepend
1.4.11	AA	non-text contrast	accessibilityFeature: highContrastDisplay
1.4.3	AA	minimum contrast	accessibilityFeature: highContrastDisplay
1.4.6	AAA	Enhanced Contrast	accessibilityFeature: highContrastDisplay
1.3.3	A	sensory characteristics	accessMode: visual

TABLE 2. Correlation of accessibility metadata with visual digital resources.

Criteria WCAG	Level	Description	Metadata and identified value
1.2.1	A	Audio only or video only (recorded)	accessMode:auditory y accessMode: visual
1.2.2	A	Audio synchronized with subtitles (recorded)	accessibilityFeature: captions
1.2.3	A	Video with audio description or alternative medium (recorded)	accessibilityFeature: audioDescription
1.2.5	AA	Video with audio description (recorded)	accessibilityFeature: audioDescription
1.2.7	AAA	Video with extended audio description (recorded)	accessibilityFeature: audioDescription
1.2.8	AAA	Video alone or half synchronized with an alternative medium (recorded)	accessibilityFeature: ttsMarkup
1.2.6	AAA	Audio synchronized with sign language (recorded)	accessibilityFeature: signLanguage
1.4.2	A	audio monitoring	accessibility: higtcontrastaudio
1.4.7	AAA	Low or no background sound	accessibilityFeature: highContrastAudio_no Background accessibilityFeature: highContrastAudio_ switchableBackground
1.3.3	A	sensory characteristics	accessMode: auditory
3.1.6	AAA	Pronunciation	accessibilityFeature: synchronizedAudioText

B. PNP - ADAPTABILITY IN LEARNING OBJECTS

UDL is considered as the supporting model for assessing the adaptability of a learning object based on the learner's needs and preferences. The following tables show the identified correlation of the UDL guidelines and the metadata [8], [16], as well as some proposed metadata.

1) PRINCIPLE OF REPRESENTATION

We analyze 6 criteria directly related to the level of interactivity established in WCAG and its relationship with Schema.org metadata specified in Table 5

TABLE 3. Correlation of accessibility metadata with textual digital resources.

Criteria WCAG	Level	Description	Metadata and identified value
1.3.3	A	sensory characteristics	accesMode: textual
2.4.2	A	Page titling	accessibilityFeature: structuralNavigation
2.4.4	A	Purpose of links (in context)	accessibilityFeature: structuralNavigation
2.4.9	AAA	Purpose of links (only links)	accessibilityFeature: structuralNavigation
2.4.6	AA	Headers and labels	accessibilityfeature: structuralNavigation accessibilityfeature: readingOrder
3.2.4	AA	Consistent identification	accessibilityFeature: structuralNavigation accessibilityFeature: bookmarks
3.3.2	A	labels or instructions	accessibilityFeature: bookmarks
3.3.5	AAA	Help	accessibilityFeature: annotations
3.1.3	AAA	unusual words	Alignment types: textComplexity
3.1.4	AAA	abbreviations	Alignment types: textComplexity
3.1.5	AAA	reading level	Alignment types: readingLevel
1.3.1	A	Information and relationships	accessibilityFeature: structuralNavigation OR accessibilityFeature: index
1.4.4	AA	Text size change	accessibilityFeature: displayTransformabilityfontSize
2.4.1	A	avoid blocks	accessibilityFeature: bookmarks
3.1.2	AA	Language of the parts of the page	inLanguage
3.1.6	AAA	Pronunciation	accessibilityFeature: synchronizedAudioText
1.4.11	AA	non-text contrast	accessibilityFeature: highContrastDisplay
1.4.3	AA	minimum contrast	accessibilityFeature: highContrastDisplay
1.4.6	AAA	Enhanced Contrast	accessibilityFeature: highContrastDisplay

TABLE 4. Correlation of accessibility metadata with level of interactivity.

Criteria	Level	Description	Metadata and identified value
2.3.1	A	Threshold of three flashes or less	accessibilityHazard: noFlashingHazard
2.3.2	AAA	three flashes	accessibilityHazard: noFlashingHazard
2.2.9	AAA	Animations from interactions	accessibilityHazard: noMotionSimulationHazard
2.1.1	A	Keyboard	accessibilitycontrol: fullKeyboardControl
2.4.3	A	Focus Order	
2.6.1	A	motion performance	accessibilitycontrol: fullKeyvoiceControl/ fullMouseControl

2) PRINCIPLE OF EXPRESSION

3 guidelines and 10 items are analyzed to establish correlation with the Schema metadata explained in Table 6

TABLE 5. Correlation metadata of adaptability with UDL representation network.

Directive	Item	Metadata and identified value
Presents information in different formats (perception)	1. Text	accessMode: auditory
	2. Iconographic (photos, images, logos, icons, infographics)	accessMode:text
	3. Audiovisual (vIdeo, audio).	accessMode: visual
	4. Interactive and/or multimedia material.	
Use support elements to decode the information:	5. A direct, simple and hierarchical syntax is used in order of relevance	accessibilityFeature: structuralNavigation
	6. Includes options to clarify oral, written and mathematical language. For example, using: glossary, translator, text to speech converter, images, audio descriptions, video subtitles, calculator, etc.	accessibilityFeature: MathML accessibilityFeature: captions accessibilityFeature: audioDescription accessibilityFeature: synchronizedAudio Text
	7. The multimedia elements are conveniently labeled (title, description of images or video, authorship...).	accessibilityfeature= ReadingOrder accessibilityfeature= HeadingAccording MainTheme
Provides options for understanding	8. Guide the use of the resource with a navigation menu	accessibiltyFeature: index
	9. The main ideas are differentiated from the secondary ones	accessibilityFeature: bookmarks
	10. Theoretical information is supported with examples, analogies, summaries, complementary documents and/or simulations	AccessibilityFeature: annotations
	11. Includes consultation or extension links, which must be opened in a new browser window.	accessibilityFeature: bookmarks

TABLE 6. Adaptability metadata correlation with expression network UDL.

Directive	Item	Metadata and identified value
Allows multiple means to interact with the material	1. It is cross-platform and multi-device	accesibilityAPI: ARIA
	2. The materials, all or part, can be consulted in digital and analog format	N/A it's always digital
	3. Enables the use of technical aids if necessary	accessibilityControl: fullKeyboardControl
The response model is varied in the activities (expression and communication)	4. There are different possibilities for students to communicate what they know: textual, graphic, audiovisual, interactive, kinesthetic, musical	accessModerequiered: 'textual', 'visual', 'auditory'
	5. Various final products are requested, both in digital and analog format	N/A it's always digital
	6. There are individual and collective activities	interactivityType: 'active', 'expositive', or 'mixed'
	7. Allows students to choose, among several options, in certain activities, materials and/or tools	educationalUse: 'assigment', 'group work´
Facilitates the development of executive functions	8. Students know what is expected of them; that is, they know the learning objectives and the rules of operation, from the beginning	aligmentType: prerequisite
	9. Offer examples, templates, tutorials, tips, autocorrect and/or supporting models	learningResourceType: 'template', 'tutorial', 'tips', 'autocorrectors', 'support models'
	10. Self-monitoring tools are provided: checklist, stopwatch, key questions, self-instructions, etc.	interactivityType: 'active', 'expositive', or 'mixed' learningResourceType: autoControlTool

3) MOTIVATION PRINCIPLE

3 guidelines and 8 items are analyzed to establish correlation with the Schema metadata explained in Table 7

With this background, a model for evaluating the accessibility and adaptability of an LO according to its metadata is proposed.

IV. METHODOLOGY

A. ECOSYSTEM ARCHITECTURE

The proposed ecosystem and its architecture (Figure 4), identifies 4 layers of interaction that requires the loading of the learning object with its respective packaging in educational format SCORM, IMS, Common Cartridge, generally the metadata of frequent use responds to LOM and the programs to perform LO generate them by default, however it does not consider the accessibility metadata. That is why the ecosystem considers the creation of tools that facilitate the automatic labeling of accessibility metadata, OER ADAP and LOMPAD WEB Schema. The LO can then be entered into a repository that will facilitate the evaluation. In Figure 4 a diagram of the general architecture is shown.

In relation to the tools generated based on the knowledge base we have:

1) OER ADAPT

This tool aims to support the teacher or educational content creator in the adaptation of a learning object, considering accessibility features (Figure 5). OerAdap is developed in Django as Backend and Angular as Frontend, it can be accessed through the following url: https://oeradap.edutech-project.org.

TABLE 7. Adaptability metadata correlation with motivation network UDL.

Directive	ITEM	Metadata and identified value
Provides options to capture interest	1. Includes suggestive titles and/or different ways to arouse curiosity: challenges, challenges, surprise effects, help characters, enigmas, unknowns, tricks, locks to open, tests to overcome, curiosities	interactivityType: 'active', 'expositive', or 'mixed' motivationType: 'challenges', 'helpCharacter', 'tricks'
	2. The writing uses a language close to the slang of the recipients. Example: wording in the first person plural, understandable vocabulary, etc.	aligmentType: textComplexity / complexityLevel redactionType: firstperson
Provides options to maintain effort and persistence	3. The active role of the student prevails, through the use of active methodologies and cooperative learning	interactiveType: 'active', 'expositive' or 'mixed'
	4. The goal is divided into different phases or sub-goals, from least to most complex (scaffolding).	learningResourceType: scaffolding
	5. Includes reward and incentive elements.	
	6. It has automatic and corrective feedback in some activities, aimed at overcoming	accessibilityFeature: annotations
Provides options for self-regulation	7. There are different evaluation instruments. For example: checklist, learning target, questionnaire or test, estimation scales, evaluation rubrics with different levels of achievement	educationalUse: assessment
	8. Allows self-assessment and co-assessment.	learningResourceType: selfAppraisal or learningResourceType: coEvatuation
	9. Includes actions to enhance reflection on learning (diary or learning portfolio).	learningResourceType: scaffolding

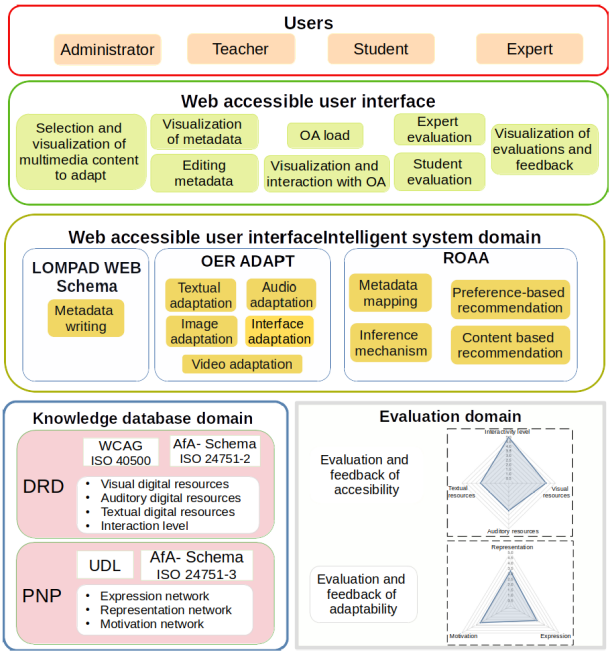

FIGURE 4. General architecture of the ecosystem that includes the users and their different profiles, the user interface domain with its different actions, the knowledge database domain with accessibility information, and the evaluation domain with the evaluation mechanisms.

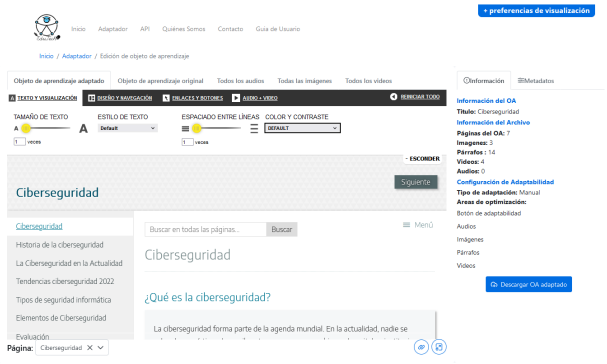

FIGURE 5. Screenshot of OerAdap tool where the accessibility adaptation to learning objects can be made.

The tool can be loaded with a learning object in one of the educational formats mentioned above, then the user can choose which multimedia educational resource found in the LO to adapt, whether videos, audios, images, paragraphs or just integrate the accessibility preferences bar. With this parameter, the system sweeps through the different HTML files of the LO in search of the tags that contain these resources and their respective paths. Once the resources have been identified, the user is presented with a pre-visualization of the learning object followed by the adaptations that can be made to the page, which are as follows:

- Video adaptation: The system replaces the video player with an accessible one, developed by the "Floe" project [17]. This player has an accessible, minimized interface and provides captioning and text synchronized with the audio. The system downloads the video in case it is on another platform, in the case of youtube videos it downloads the video and the subtitle file (.str) in two predefined languages, Spanish and English. In case the video does not have subtitles or is on another platform, the system extracts the audio from the video and analyzes it through Automatic Speech Recognition (ASR) in order to extract the different sentences that make up the explanation given by a narrator or people involved in the video. This generates the subtitling file to be used by the player. Similarly, the player requires a vtt file that contains video subtitles written with the WebVTT standard to display timed text of the video playback, this file in both cases is generated by the system from the.srt file.
- Adaptation of images: The system shows the user the images found in each of the pages, along with the description found in the case that it has one, otherwise the user can add or modify the description. The system also provides options for the different images that can be found in the LO, being the case of table images, the system allows to manually add one to a table, which will replace the image. In the event of equations, the user can

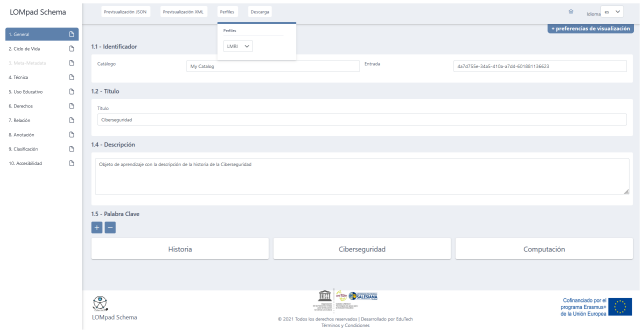

FIGURE 6. Screenshot of the LOMpad Web tool in which metadata can be edited or integrated into learning objects.

replace the equation image with an equation written in MathML.

- Paragraph adaptation: The system identifies the paragraph tags of the html files and shows the user paragraphs that exceed a certain number of characters, to which it gives the option to add the easy read option or generate an audio of the paragraph. In these cases, icons will be displayed below each paragraph.
- Audio adaptation: The system allows you to identify audios found in learning objects and automatically generate a verbatim transcript or manually transcribe the audio.
- Accessibility Bar: By selecting the accessibility preferences bar option which was taken from the open source Fluid Project [17] Preferences Framework. This bar has a series of parameters that help to make the educational resource accessible, such as: change of font size, screen contrast, etc. The system embeds in the different html files of the preferences framework including CSS, HTML and JavaScript files.

When the different adaptations are made, the system embeds in the XML metadata file in LOM format the metadata proposed in the research.

2) LOMPAD WEB

This tool seeks to support in the correct labeling of metadata based on the standard of the LOMPAD tool, and incorporating Schema.org initiatives with LRMI, identifying the accessibility metadata contributed by [18] and [19], and the quality considerations of [20], which aim to add a set of classes and properties to the description of learning resources on a par with other standards with an emphasis on accessibility. For this purpose, a previous analysis of previous proposals and specifications proposed for the LOMPAD tool, which considers IEEE-LOM, was carried out (Figure 6)

IEEE LOM describes a conceptual data schema that defines the metadata structure for learning objects. It establishes a schema divided into 9 categories of metadata elements, each of which includes several metadata elements or subcategories that allow learning objects to be 'tagged'' at a high level of detail, thus we have a:

- General: groups general information that describes the learning object as a whole.
- Life cycle: includes characteristics related to the history and current state of the learning object, and everything that has affected it during its evolution.
- Meta-Metadata: allows you to include information about the metadata instance itself.
- Technical requirements: groups information on requirements and technical characteristics of the learning object.
- Pedagogical characteristics: includes information on the pedagogical and educational characteristics of the learning object.
- Rights of use: it groups information on intellectual property and conditions of use for the learning object.
- Relationships: groups characteristics that describe the relationships between this learning object and other related objects.
- Annotations: provides comments on the pedagogical use of the learning object and provides information on when and by whom the comments were created.
- Classification: describes the learning object according to a certain classification system.

LOMPAD WEB performs a mapping of the information in the XML metadata file to show it to the user so that he/she can modify it without having to add it again. It also incorporates the Learning Resource Metadata Initiative (LRMI), Schema.org and its accessibility metadata. For this purpose, a new profile known as LRMI is added to the Lompad tool menu, and a 10th category called ''10. Accessibility'' is displayed, which contains the same scheme as other LOMPAD windows considering the fields:

- 10.1 accessibilitySummary
- 10.2 accessibilityFeature
- 10.3 accessibilityHazard
- 10.4 accessibilityControl
- 10.5 accessibilityAPI

Similarly, the addition of the following fields is considered in category 8 ''Annotations'' according to the proposal of. [21]:

- 8.4 AccessMode
- 8.5 AccessModeSufficient
- 8.6 Role

The tool allows exporting metadata in XML and Json format and is available from the link https://lompads.edutech-project.org.

3) RALO (REPOSITORY OF ACCESSIBLE LEARNING OBJECTS)

Based on the assessment areas defined in section III for both digital resources and for establishing student preferences, a question-fed assessment is provided for the accessibility expert and for the student and their interaction experience.

The questions are based on and distributed within each evaluation area according to the guidelines and metadata analyzed above, these questions have the option to answer

Yes, No, Partially and Not Applicable, where the score will be defined according to the positive contribution in accessibility and adaptability of the learning object.

The Learning Objects repository is developed in Django as Backend and Angular as Frontend, and is available through the following link: https://repositorio.edutech-project.org.

The tool has three main usage profiles, these being:

- Student Profile: Users with this profile enjoy an LO recommendation system based on their selected accessibility preferences when registering, they can search for LOs by different filters, visualize and interact with the selected LO and perform an evaluation through a form to determine its adaptability by means of the principles.
- Expert Profile: Users with this profile help to maintain a repository of LOs with quality and accessibility. Experts can view the different LOs loaded in the repository, interact with it and perform the evaluation through the form, to determine the accessibility of the same by means of the different concepts: visual, auditory, textual digital resources and level of interactivity.
- Teacher Profile: Users with this profile are mainly in charge of uploading their LOs to the repository. They will be able to see the results of their evaluations through graphs and a score in different areas. At the same time, the teacher will be able to visualize feedback that the system generates automatically based on the answers of the evaluation of the teacher and the student. This will allow to improve or correct which resource can be accessed by all students.

In relation to the Metadata Evaluation, this is fed by the contributions of the questions posed to experts and students, as well as the automated metadata of the aforementioned tools, for which their category is considered for both accessibility and adaptability, as well as relevance, generating the following Equation 1

$$(\overline{X} = \frac{X_1 + X_2 + X_3 + X_4 + \ldots + X_n}{N}) \times \text{Evaluation Formula} \quad (1)$$

where X_1, X_2,...X_n represent the score that each metadata obtained in the evaluation. N represents the total amount of accessibility and adaptability metadata identified in the evaluation for each category noted in the proposal.

V. EXPERIMENTATION AND RESULTS

The validation of the model is based on the interaction study and analysis of regular and disabled students (Case 1), as well as teachers who develop LO (Case 2). In relation to the evaluation of accessibility and adaptability experts, a decision support module was developed using Borda voting schemes (Case 3). Likewise, a validation process was carried out using the iter-rater agreement method: Kendall's Coefficient of Concordance W, in order to determine whether there was consensus among the experts' scores.

The validation of comparisons in students and teachers was reviewed with the initial evaluations of the LOs without considering accessibility and the subsequent review of the same, considering accessibility and adaptability of LOs to determine differences, assessments and justifications on the methodology or the need for modification in disagreements.

Automatic evaluation effectiveness is intended to assess the tools generated based on their usability and scalability.

Three case studies are established to validate the application of the proposed models, considering an initial baseline of accessibility, adaptability and metadata.

The case studies respond to a procedural analysis for their overall design, data collection, applied analysis, research results, discussion and main conclusions.

The following research questions are addressed:

- What are the considerations for generating accessible learning objects?
- What are the characteristics and barriers that do or do not allow a student with a disability to achieve learning with an LO?
- How can existing standards and tools related to accessibility contribute to generate accessible LOs?

Data sources for the case studies are used as sources of data:

- 10 original LOs and their adapted versions,
- 8 students, 3 of them with disabilities,
- 5 teachers with experience in the generation of LOs
- 5 accessibility experts to validate the model proposal.

The mixed method for the research design is determined, considering the primary data from the interviews and secondary data from the evaluation questionnaires.

The evaluation questionnaires respond to a descriptive and comparative approach. The monitoring of an accessible resource considers the recruitment of a control group to compare the experiences of barriers and accessibility features. The research considers demographic questions in its 3 cases.

Case 1: Student Perspective (LO Evaluation in RALO) We worked with a sample of 8 university students from different careers who were tested in the Gesell Chamber to establish possible emotional parameters. Three students are disabled. The age of the students is in the range of 20 to 26 years (mean 22.375, SD 1.999) and of this group 3 were women and 5 men. Table 8 shows the summary of the interaction process of the students with the LO.

Interaction results According to the challenges posed, questions related to navigability, usability and evaluation are

TABLE 8. Student demographics.

Participant	Age	Genders	Disability	Careers	Total time
Student 1	20	Male	Physical	Electronics	35 min
Student 2	23	Female	Auditory	Mechatronic	38 min
Student 3	22	Female	Visual	Education	40 min
Student 4	26	Male	No	System	30 min
Student 5	22	Male	No	Biomedicine	32 min
Student 6	22	Male	No	Biomedicine	33 min
Student 7	20	Male	No	Computation	30 min
Student 8	24	Female	No	Computation	31 min

TABLE 9. Student interaction results.

Participant	Interaction platform	Clear buttons and links	Relevance of LO information	Evaluation LO	Navigation interaction (keyboard/ mouse)	Evaluation feedback
Student 1	Very easy	Yes	Very relevant	Very easy	Very easy	Very relevant
Student 2	Easy	Yes	Very relevant	Very easy	Very easy	Very relevant
Student 3	Regular	Yes	Relevant	Regular	Easy	Very relevant
Student 4	Easy	Yes	Something relevant	Very easy	Regular	Very relevant
Student 5	Easy	Yes	Very relevant	Easy	Easy	Very relevant
Student 6	Very easy	Yes	Relevant	Hard	Easy	Very relevant
Student 7	Easy	Yes	Very relevant	Easy	Very easy	Very relevant
Student 8	Very easy	Partially	Very relevant	Easy	Easy	Something relevant

TABLE 10. Analysis of student expectations.

Participant	challenge achievement	Initial expectation	Later expectation	RALO Utility
Student 1	was able to finish the challenge	10	10	10
Student 2	was able to finish the challenge	5	10	10
Student 3	was able to finish the challenge	9	8	9
Student 4	was able to finish the challenge	7	9	10
Student 5	was able to finish the challenge	8	10	9
Student 6	was able to finish the challenge	7	8	7
Student 7	was able to finish the challenge	9	10	10
Student 8	not sure if finished the challenge	10	10	10

formulated. Each question considers the Likert scale. The results obtained are shown in Table 9:

In relation to the analysis of achievements in the challenges posed, according to the proposed protocol, questions were established that invite the interviewee to analyze his or her perception of achievement, establishing as a possibility whether he or she was able to achieve it, if he or she was not able to achieve it or if he or she is not sure if he or she achieved it. The questions related to expectation and usefulness were established as a satisfaction scale from 1 to 10, where 10 is very high and 1 is very low. Table 10 indicates the responses captured:

Evaluation Reports

With the sample of 8 students, it is established that the time spent interacting with the review of an LO and its evaluation

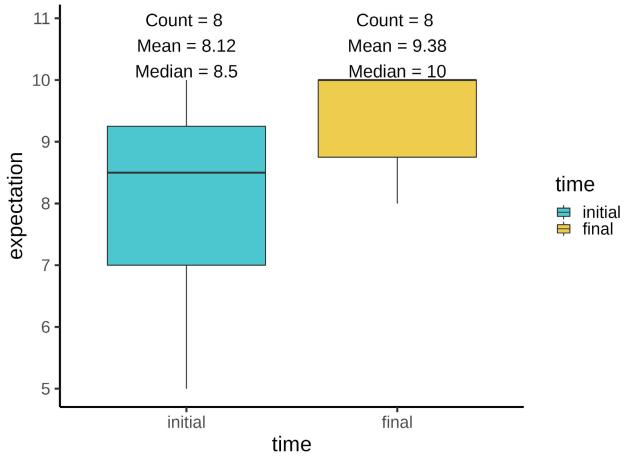

FIGURE 7. Initial expectation of students vs. final expectation of the original LO and its adapted version.

fluctuates in the range of 30 to 40 minutes (mean = 22.375, SD = 3.73).

The tool generated to store accessible learning objects and their evaluation, presents an average initial expectation by the students of 8.12 and after the tests the final expectation is 9.37.

In order to determine whether there was a change (error variance) of each student in relation to the original LO and the adapted LO, the paired samples Wilcoxon test was applied (since the data are not normally distributed) [22]. As can be seen in the box-and-whisker plot of Figure 5, on the left we can see the initial expectation of the original LO, while on the right we can see the final expectation in relation to the adapted LO. With this simple graphical inspection it can be seen that there is a substantial improvement in this parameter and an increase in the mean from 8.12 to 9.38.

However, in order to determine whether there was a significant change, the following null hypothesis (and its alternative version) was proposed:

- H_o: There is no effect or increase in students' expectation in relation to the original LO and the adapted LO.
- H_a: The adaptation of the object increased the expectation of the students.

To perform this analysis, we have assumed the following aspects:

- The expectation variables (initial and final) are on a scale.
- The differences in the observations of the variables are not normally distributed.
- A baseline and endline measure of student expectation was conducted.
- Data were randomly drawn from the student sample.

The Wilcoxon test was calculated using the statistical software R (version 4.2.1) considering that the mean of the students' expectation is lower with the original LO. A p-value equal to 0.04449 was obtained, which is less than the significance level alpha (0.05). We can conclude that the mean

TABLE 11. Teacher demographics.

Participant	Age	Genders	Disability	careers	Total time
Teacher 1	44	Female	No	Automotive	55 min
Teacher 2	37	Female	No	Computing	50 min
Teacher 3	48	Female	No	Biomedicine	45 min
Teacher 4	40	Male	Visual	System	56 min
Teacher 5	39	Male	Visual	Education	63 min
Teacher 6	39	Male	No	Biomedicine	40 min
Teacher 7	34	Female	No	Biomedicine	70 min

expectation of the LO before adaptation is significantly less from mean expectation after the adaptation.

The evaluation of an LO by a student responds to questions focused on the 3 UDL networks, so it is necessary to determine more characteristics than a basic evaluation. This evaluation of LO at a difficult or regular level was particularly detected in older regular students. The feedback delivered by the tool to each student had a particular acceptance to generate a process of constant improvement.

Case 2: Teachers' perspective interaction and evaluation feedback

A sample of 5 university teachers from different careers who were tested in the Gesell Chamber and by videoconference was established. Of this group of participants, the age range is between 37 and 48 years old (mean = 41.6, SD = 4.39), 3 are women and 2 are men, and two teachers are disabled. Below, in Table 10 a summary of the participants' demographics can be seen, as well as the time they required to interact and review with the LOs.

According to the challenges posed, questions related to navigability, usability and evaluation are formulated. Each question considers the Likert scale. In Table 12 the obtained results are presented:

In relation to the analysis of achievements in the challenges posed, according to the proposed protocol, questions were established that invite the interviewee to analyze his or her perception of achievement, establishing as a possibility whether he or she was able to achieve it, if he or she was not able to achieve it or if he or she is not sure if he or she achieved it. The questions related to expectation and usefulness were established as a satisfaction scale from 1 to 10, where 10 is very high and 1 is very low. Table 13 indicates the captured responses.

Evaluation Reports With a sample of 5 teachers, it was determined that the time spent interacting with an LO upload and its evaluation feedback ranged from 45 to 63 minutes (mean = 53.8, SD = 6.76).

The tool generated to upload accessible learning objects and their evaluation information on accessibility and adaptability, presents an average initial expectation by teachers of 7.6 and after the tests, the final expectation is 8.2.

In order to determine whether there was a change (error variance) of each teacher in relation to the original LO and the adapted LO, in this case the paired samples Wilcoxon test was also applied (since the data are not normally distributed) [22]. As can be seen in the box-and-whisker plot of Figure 8, on the left we can see the initial expectation of the original LO, while on the right we can see the final expectation in relation to the adapted LO. With this simple graphical inspection it can be seen that there is no substantial improvement in this parameter and the increase is not very significant (from 7.6 to 8.2).

TABLE 12. Results of teacher interaction.

Participant	platform interaction	Clear buttons and links	Upload LO	Information on LOs and options	Navigation interaction (keyboard/ mouse)
Teacher 1	Very easy	Yes	was able to finish the challenge	Something relevant	Very easy
Teacher 2	Very easy	Yes	was able to finish the challenge	Very relevant	Very easy
Teacher 3	Very easy	Yes	was able to finish the challenge	Very relevant	Easy
Teacher 4	Regular	Partially	not sure if finished the challenge	Relevant	Regular
Teacher 5	Difficult	Partially	Was not able to finish the challenge	Relevant	Regular
Teacher 6	Easy	Yes	was able to finish the challenge	Relevant	Easy
Teacher 7	Very easy	Yes	was able to finish the challenge	Very relevant	Easy

TABLE 13. Analysis of teaching achievements.

Participant	LO accessibility and adaptability feedback	Initial expectation	Later expectation	Utility RALO
Teacher 1	something relevant	10	6	10
Teacher 2	Very relevant	8	10	9
Teacher 3	Very relevant	7	9	10
Teacher 4	Very relevant	7	9	10
Teacher 5	Relevant	6	7	8
Teacher 6	Relevant	5	8	10
Teacher 7	Very relevant	7	10	10

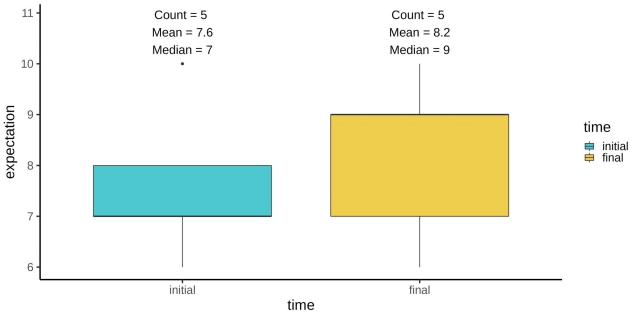

FIGURE 8. Initial expectation of teachers vs. final expectation of the original LO and its adapted version.

With this, and in the same way as in the case of students, the following null hypothesis (and its alternative version) was proposed:

- H_o: There is no effect or increase in teachers' expectation in relation to the original LO and the adapted LO.
- H_a: The adaptation of the object increased the teachers' expectations.

A p-value equal to 0.2914 was obtained, which is greater than the significance level alpha (0.05). We can conclude that the mean expectation of the LO before adaptation is not significantly less from mean expectation after the adaptation.

The accessibility and adaptability feedback of an LO responds to a process that begins with an initial diagnosis to establish basic questions that the teacher must know about his or her learning object. Although most teachers determine the need and relevance of accessibility feedback for their LO, working with resources from different manufacturers and authors does not always make it possible for a teacher with a disability to interact with the resources, even if the page is accessible. The feedback given to each teacher, both by the expert and the student, constitutes a process of constant improvement, where co-design and co-evaluation strengthen the development of accessible LOs with greater reusability and scalability.

Case 3: Decision support system for accessibility and adaptability criteria of LOs: a proposal based on Borda Voting schemes.

The Borda voting scheme is a method that has been successfully used to address problems in various areas such as decision support in the field of psychology (consensus of methods for psychological profiling analysis) [23], elimination of dataset imbalance for financial fraud detection [23], the selection of essential features for the improvement of rice production through the fusion of descriptors obtained from ranking methodologies [24], feature selection based on metaheuristic optimization algorithms (Grey Wolf Algorithm) and Borda voting schemes, [24], among others.

In this line, in the field of analysis of accessible educational resources, the work done by human experts is fundamental and, on the other hand, there is a great variety of criteria regarding the relevance of certain metadata related to the WCAG 2.1 accessibility guidelines. Therefore, a decision support module is proposed to perform this analysis and obtain the consensus of various experts and criteria using Borda voting schemes.

The Borda voting method used in the module supporting the relevance analysis of questions associated with metadata by expert consensus is defined as follows: be $\mathcal{M}(c) = [m_1(c), m_2(), \ldots., m_k(c)]$ finite set of metadata according to criterion (c). The value of k will depend on criterion (c), since for certain criteria there may be up to 10 metadata. It is assumed that $E = [e_1, e_2, \ldots, e_m,]$ represents the set of expert evaluators. Given these two sets, it is important to take into account that k$\geq$ 3 and m $\geq$ 3, in order to be able to apply the Borda voting method. Moreover, the following conditions must be satisfied:

TABLE 14. Priority of expert questions: Visual digital resources.

Question	E1	E2	E3	E4	E5
Do the images have alt text?	1	1	1	1	1
Are there images that have embedded text and consider an adequate description?	2	2	3	3	3
Is there a properly labeled color dependency?	4	3	2	2	4
Are optimal contrasts met in the presentation of information?	3	4	4	4	2

- R is an asymmetric binary preference relation of M that satisfies the following proposition: if m_i(c) Rm_j(c) occurs then m_j(c) Rm_i(c) cannot occur.
- I is an indifference representing the non-preference for a given expert: if m_i(c) Im_j(c) means that there is neither m_i(c) Rm_j(c) nor m_j(c) Rm_i(c).
- m_i(c) (R $\cup$ I) m_j(c) represents a weak preference relation and means that there can exist m_i(c) Rm_j(c) orm_i(c) Im_j(c).
- m_i(c) $R^k m_j$(c) represents a preference ratio of the metadata tool k,(k=1,2,…..,M) among the set of alternatives (profiles) M

Given these two sets, it is important to take into account that for this evaluation we had the assessment of priorities of 5 experts in Accessibility and Adaptability who were asked to establish an order of preference. Next, the experts' data is established and the application of a voting scheme with visual digital resources where 4 questions are defined and it is requested to establish the prioritization from 1 to 4, being 1 the highest preference and 4 the lowest preference, explaining that it is not possible to repeat. With the experts' answers, the Table 7 is created.

Given these two sets, it is important to take into account that for this evaluation we had the assessment of priorities of 5 experts in Accessibility and Adaptability who were asked to establish an order of preference. Next, the experts' data is established and the application of a voting scheme with visual digital resources where 4 questions are defined and it is requested to establish the prioritization from 1 to 4, being 1 the highest preference and 4 the lowest preference, explaining that it is not possible to repeat. With the experts' answers, the Table 14 is created.

With this, the decision support module automatically generates the preference matrices shown in Figure 9. As can be seen, for the matrix, expert 1 indicated the preference of the first criterion over the others, so the system places 1 in the following row-column pairs: 1 – 2, 1 - 4 and 1 - 3. Similarly, for expert 1 the second criterion takes precedence over criteria 4 and 3, so the system places 1 in the following row-column pairs: 2 - 4 and 2 - 3. Finally, for expert 1 the fourth criterion is more important than the third criterion, so 1 is placed in row 4 and column 3.

In the same way the system proceeds to generate the matrices for the other 4 experts. Once all the matrices are available, the system makes a sum by rows, with which the votes for each criterion are established, having in this case 15 votes

$$DVR(e_1) = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{pmatrix} DVR(e_2) = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

$$DVR(e_3) = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} DVR(e_4) = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

$$DVR(e_5) = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 \end{pmatrix} DVR = \begin{pmatrix} 15 \\ 6 \\ 7 \\ 2 \end{pmatrix}$$

FIGURE 9. Borda Voting analysis Visual digital resources.

TABLE 15. Order of preference in Visual digital resources.

Question	Final vote (order of preference)
Do the images have alt text?	15 (1ero)
Is there a properly labeled color dependency?	7 (2do)
Are there images that have embedded text and consider an adequate description?	6 (3ero)
Are optimal contrasts met in the presentation of information?	2 (4to)

for the first criterion, 6 votes for the second, 7 for the third and 2 for the fourth. With these votes an order of preference or relevance of the criteria is established, as can be seen in Table 15:

Similar analyses are performed for all categories of DRD and PNP. The experience in the development and use of LOs constitutes an important diagnostic basis to focus the case studies. The interaction with a tool that includes the storage and evaluation of LOs, such as the repository, requires an analysis of the interaction with the tool, which involves several profiles. The teacher or LO generator, the student consumer and evaluator from his learning experience and the accessibility expert, who points out the evaluations made. In the case studies with students and teachers, positive conclusions were reached regarding the ease of use of the tool and visualization of everything it entails, motivating autonomous learning in a more intuitive way, generating a self-assessment of knowledge and skills.

In relation to the time used to interact with the platform and carry out the evaluation, most of them say that it is adequate and can meet the challenges posed. In particular, the use of search filters based on the user's needs and preferences, the simple and intuitive interface when presenting the educational resources, the evaluation feedback and the full screen display of the learning object are particularly pleasing.

In relation to the problems detected, it is established that the evaluation by the student is long to perform and the need for an introduction or help on certain purposes of the tool. The interaction of people with disabilities was optimal, with the exception of total visual impairment, since the different screen readers and browser preferences require a more in-depth review of certain fields.

The contribution of experts in visual impairment both in teaching and students, has established a plan for proofreading and continuous improvement based on co-design and co-evaluation with special emphasis on this disability.

Although Equation 1: considers the evaluation of accessibility and adaptability of an LO through its metadata, both for DRD and PNP, for each accessibility metadata detected, a score of 2 was established as a sign of possessing it, 1 if it partially possesses it and 0 if it does not possess it, with the option of not applicable for such metadata not to be considered in the score. After the review of experts and the establishment of LO comparisons according to the needs and preferences of students with disabilities, it is foreseen that it is necessary to consider the weight, so a greater precision in the scoring is determined Equation 2:

$$\left(\overline{X} = \frac{x_1.p_1 + x_2.p_2 + x_3.p_3 + x_4.p_4 + \ldots + x_n.p_n}{N}\right) \times \text{Post evaluation formula} \quad (2)$$

where x_1, x_2,$\ldots x_n$ represent the score that each metadata obtained in the evaluation of Yes / Partially / No / Not applicable; $p_1, p_1, \ldots p_1$ represent the weights based on the priorities analyzed with Borda voting and N represents the total amount of accessibility and adaptability metadata identified in the evaluation for each category indicated in the proposed model.

As an answer to the research questions formulated, the following is established:

- What are the considerations for generating accessible learning objects?

According to the interviews to LO developers, it is established that accessibility is not one of the main characteristics to develop digital educational media, since there are many trends to generate them and the proliferation of tools, techniques and strategies is constantly increasing, so most teachers interviewed say that their learning curve is still in the generation of digital resources, and therefore the consideration of accessibility and the proper use of metadata, is an additional work that they prefer to be established automatically, without further emphasis on it.

It is necessary to strengthen the use of support tools that facilitate the correct labeling of a learning object, and whose action does not constitute an additional effort to the developer of a resource, but is pre-established as we move forward with a culture of inclusion based on the diverse learning experiences of the student, analyzed from their variability and detected barriers and not from their disability and limitations. The teaching experience with students with disabilities, raises actions to develop accessible and adaptable educational resources.

- What are the characteristics and barriers that do or do not allow a student with a disability to achieve learning with an LO?

The characteristics and interaction barriers detected in an LO that works on the web, are the same as those identified by the WCAG, however, its educational characteristic generates a deepening of the teaching and the need to adapt to

the diversity of learning styles. Consequently, the range is widened, since it is not frequent that a person has only one disability, and from this information can consume resources ''labeled'' for that disability. The achievement of learning is given by different evaluations that respond to different times and circumstances. Although a learning object can encourage the search for information, by itself, it does not achieve learning but rather motivation, and digital educational resources facilitate autonomy, reuse and generation of new knowledge.

The analysis of use cases with both regular and disabled students establishes that the duration of interaction of an LO will be correlated with motivation. The more concrete and interactive it is, the longer the student's attention will remain on the resource. The barriers detected, whether in access or comprehension, generate an immediate abandonment of the resource and possibly frustration.

It should be noted that the greatest number of barriers that require constant review based on the tests performed, is detected in the total visual impairment, since multimedia features of a resource overlap and are often not fully covered by a screen reader and its different versions. However, the diversity of visual, auditory, textual and interactive digital resources could become the support required from multiple forms of presentation to advance in the understanding of a major topic.

- How can existing standards and tools related to accessibility contribute to generate accessible LOs?

The approach and support of the tools generated for the testing process, respond to the support of applicability in accessible LOs, endorsed in several existing standards for Learning Objects such as LOM and LRMI. For accessibility, ISO 24751-2, AfA, Schema.org, ISO 40500 (WCAG 2.0) and WCAG 2.1 considerations were taken into account. For adaptability, UDL, ISO 24751-3, AfA and Schema were considered.

Learning in a web environment is one of the main ways to access education, so the existing regulations that support accessible interaction are an important basis to advance in the support of online training and all the resources generated in a virtual teaching environment. The different didactic educational materials must be analyzed from the different characteristics of their granularity, where their universal design, flexibility, interoperability and reusability constitute a strong contribution to establish a scalability in the generation of learning.

In order to determine whether there was consensus among the experts, the inter-rater agreement was analyzed. For this purpose, we calculated the Kendall's Coefficient of Concordance [25].). The calculation process was carried out using R statistical software (version 4.1.2) and the following hypotheses were made regarding the agreement among the experts:

- H_o: There is no consensus among experts for the proposed metadata.
- H_a: Yes, there is a consensus among experts for the proposed metadata.

TABLE 16. Kendall's Coefficient of Concordance W obtained for inter-rater agreement analysis.

	Category	Kendall´s W	x2	p=value	Agreement level
DRD	visual digital resources	0,664	9,96	0,0189	substantial
	Auditory digital resources	0,752	26,3	0,000439	substantial
	Interactivity level	0,712	14,2	0,00657	substantial
	Textual digital resources	0,693	31,2	0,000277	substantial
PNP	representation network	0,364	16,4	0,0595	Fair
	expression network	0,693	24,3	0,00102	Substantial
	motivation network	0,461	16,1	0,0239	Fair

As can be seen in Table 16, for Kendall's Coefficient of Concordance W we worked with the interpretation proposed by [26]:

- $0.00 <= w < 0.20$ - Slight agreement
- $0.20 <= w < 0.40$ - Fair agreement
- $0.40 <= w < 0.60$ - Moderate agreement
- $0.60 <= w < 0.80$ - Substantial agreement
- $w >= 0.80$ - Almost perfect agreement

According to the Kendall's Coefficient it can be seen that there is a ''Substantial agreement'' for all the metadata, except for the ''Expression network'' and the ''Motivation network'', where we can see that the consensus is ''very weak'' and ''moderate'', respectively. For the metadata where there is ''Substantial agreement'' the null hypothesis is rejected, since the p-value is less than 0.05 (statistically significant).

VI. LIMITATIONS

This research presented limitations during the process and in its search to answer the interaction questions from the experience of students with disabilities. The selection of the sample is limited.

It is established that there is a scarcity of accessibility evaluation in LOs at a general level, and even more so endorsed by people with disabilities. Moreover, the available studies tend to focus more on design recommendations than on evaluating the effectiveness of their implementation and improvement process. The use of accessibility standards is subjective, in several cases it responds to evaluative models that, although they consider accessibility as a metric, it is inconsistent to reach a common implementation process, especially with regulations of different interpretation in the legislations of each country. There is a lack of references that establish an important sample of students with disabilities, their follow-up, monitoring and improvement in learning design and digital competencies, which requires more time to obtain reliable data.

VII. DISCUSSIONS AND RECOMMENDATIONS

The information from quantitative, qualitative or mixed studies focused on the impact on students with disabilities at a

general level, requires an audit and continuous improvement process that involves and commits all stakeholders within an educational project that also provides for digital competencies that support the effectiveness of an evaluative model of accessibility and adaptability of an LO. The use of accessibility metadata for models and standards in e-learning environments is supported by scientific research. ISO 24751, AfA, Schema, are analyzed and constitute the basis for the proposal of the evaluation model in DRD (Digital Resource Description). Although the accessibilities on the web led by the standards specified in the WCAG constitute the commanding voice, they do not keep in itself a direct correlation with virtual education, since the complexity of education involves several areas that not only focus on digital resources, but also on the learning characteristics of the learner, as pointed out by research of evaluative models of e-learning. With this, the student's perspective is directly related to their learning, and establishes an analysis from the adaptability of a resource based on personal needs and preferences (PNP).

Although accessibility focuses on generating scenarios that enable autonomy for all people, especially those with disabilities, research often tends to establish guidelines that label certain disabilities, reducing barriers for some and increasing them for others, and thus the digital divide does not diminish, but rather is avoided with specific justifications focused on disability. It is emerging to identify the needs and preferences of the user from their variability in learning and not from the limitation of the disability itself, so the range of options is expanded by the human diversity that is intended to cover from the needs and preferences, which may well be similar to those of another student categorized as ''regular''. In this sense, the best experiences have been given by the SAD model as a response to the diversity and variability in learning rather than labeling a particular disability.

The use of metadata in Learning Objects is not a rewarding practice, it is usually associated with the platform or developer program that may make the effort to apply standard, common or basic metadata by default. If the mandatory metadata of an LO responds to an automatic treatment, the widespread use of accessibility metadata is still not achieved, so it is necessary to generate automatic labeling tools to avoid dependence on additional knowledge to properly label a resource, transferring this effort to the tool and not to the teacher or developer and manager of educational resources.

The analysis of the use of accessibility metadata in LOs is still incipient because there is no formal agreement or consensus regulations for its adoption, especially by governing bodies such as LOM. The research in case studies shows its little use, so it is necessary to use automatic generation tools for a greater experience with the use of current metadata, which allows a better investigation of the requirements of new accessibility metadata and adaptability according to models.

Although the metadata allows the creation of new metadata according to the needs, it is still necessary the massive use of the current accessibility metadata. The proper use of metadata at a general level that responds to a common language is an optimal way to locate, consume and socialize resources. It is necessary the proper use of accessibility metadata respecting the initial standards of the LOs such as LOM and LRMI, strengthening the standardized use focused on the various efforts of ISO 24751, AfA, Schema.org, WCAG and DUA proposed in this model validated with the case studies and the conclusions obtained.

A. RECOMMENDATION AND FUTURE DIRECTIONS

Considering that UNESCO's Sustainable Development Goals (SDGs) 2030 [27] establishes in its SDG 10 the reduction of inequalities, in SDG 4 quality education and in SDG 17 Partnerships for the goals, it is emerging the importance of formalizing networks to enhance the research carried out as solutions at national, regional and Latin American level, with synergies of European experiences such as the ESVIAL project, Edutech of ERASMUS+ and sustainability plans that favor the applicability of present and future research to determine joint actions of socialization and subsequent technology transfer, supported by research networks associated with the subject matter.

It is necessary to elaborate and implement legal regulations especially in developing countries. The importance of demonstrating the benefits of education for all from the implementation of accessible LOs contributes to optimal quality assessment. More research is needed on the needs not only of specific disabilities, but also in the context of the learning experience, platform design, maintenance and inclusion of new features. The constant evaluation and improvement of accessibility in virtual education depends on the identification of needs, so establishing an ecosystem with a framework can provide recommendations and feedback of experiences through machine learning techniques. It is necessary to identify strategies by describing activities and identifying accessibility needs in educational resources. Content analysis and identification of cross-cutting strategies can feed cases that allow a combined flow to achieve change management.

The report on technology and disability [28] points out that the pandemic generated a drastic process in the use of technology in all aspects, making opportunities for labor and educational inclusion viable, however, technological advances must be accompanied by awareness processes for a culture of inclusion that eliminates prejudice, indifference, ignorance and discrimination, strengthening the acquisition of digital skills of people with disabilities, since technological advances and their tools will always be behind people and do not imply a change in social mentality. It is important to consider that the use of technological adaptations in many cases allows the elimination of barriers and the completion of studies under equal conditions. The use of technological resources and applications that facilitate understanding and interaction strengthens the process of co-design and co-evaluation in educational environments. However, it is important to consider that the acquisition of new technology

could be costly, so it is important to strengthen research in the development of free hardware and software.

The incorporation of intelligent systems could contribute in the evaluation of accessible resources and in the feedback of profiles and personalization from the user experience [29], [30]. However, the possibilities of learning scenario analysis are diverse especially in the topic of inclusion that in many cases evaluates professional competencies and skills. The implementation of intelligent agents could generate insights that feed back into the system and provide multiple alternatives as didactic strategies in learning for all.

B. CONCLUSION

This research is fed by the various models, standards and tools used for the application of accessible LOs, and proposes an ecosystem that considers the creation of tools that support the accessibility and adaptability evaluation model based on the needs and preferences of the student. It establishes the need for a publication of accessibility information suitable for an effective personalized search response according to the interaction requirements of an educational resource.

The objective of this document is to contribute to establish evaluative metrics of accessible LOs according to their accessibility and adaptability metadata to evaluate a learning object, identifying characteristics of the resource (DRD) in its visual, textual, auditory digital resources and its level of interactivity, as well as its impact on learning according to the needs and preferences (PNP) established in the networks of expression, representation and motivation of DUA. The proposal of the model identifies its potentiality and experiences that it is necessary the frequent use and socialization of the current accessibility metadata in platforms and tools for the creation of LOs, this would achieve the identification or creation of proposals based on specific evaluative models applied in an educational model.

It is established that it is possible to evaluate accessibility and adaptability in e-learning by the information contained in its metadata. However, the curvature of learning guided by awareness for a culture of educational inclusion is still in the process of development, but its growth in this period of pandemic was and continues to be drastic, so it is expected to arrive sooner to measure the impacts of learning for all. In one way or another, Education for All is supported by several issues (accessibility) but learning for all (adaptability) still requires measuring efforts and modeling knowledge. It seeks to positively impact the needs and preferences of all students through the appropriate use of metadata, especially those with disabilities. It is necessary to consider that the measurement of impact is a process of continuous monitoring and follow-up based on the sustainable development of a culture of educational inclusion supported by awareness and knowledge of potentialities and not limitations.

The knowledge base constitutes a timely field of applicability that will respond to the diversity of learning following a phase of implementation of accessibility evaluation tools and culture in LOs.

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Capítulo 3. Lista de artículos adicionales

3 Publicaciones adicionales

Otros artículos y congresos
Ingavélez-Guerra P., Pesántez-Avilés F., Robles-Bykbaev V., Yépez-Alulema J., Timbi-Sisalima C., Hilera J.R. (2016). IESAMI: An Intelligent Environment to Support the Academic Monitoring and Inclusion of Students with Disabilities in University. International Conference on Applied Human Factors and Ergonomics (AHFE 2016), 97-107, Springer. https://doi.org/10.1007/978-3-319-41962-6_9
Ingavélez-Guerra P., Cuzco-Calle, I., Calle-López, D., Oyola-Flores, C., Yambay-Aulla, I., Robles-Bykbaev, V., Hilera, J. R. (2017) An Intelligent System to Automatically Generate Video-Summaries for Accessible Learning Objects for People with Hearing Loss. International Conference on Applied Human Factors and Ergonomics (AHFE 2017), 113-122,, Springer. https://doi.org/10.1007/978-3-319-60018-5_12
Cuzco-Calle, I., Ingavélez-Guerra, P., Robles-Bykbaev, V., Calle-López, D. (2018). An interactive system to automatically generate video summaries and perform subtitles synchronization for persons with hearing loss,IEEE XXV International Conference on Electronics, Electrical Engineering and Computing (INTERCON 2018), 1-4, IEEE. https://doi.org/10.1109/INTERCON.2018.8526371.
Hilera, J.R., Estrada, F.J., Otón, S., Ingavelez, P., Timbi, C. (2018). Formalización ontológica de reglas de evaluación de accesibilidad. IX Congreso Internacional sobre Aplicación de Tecnologías de la Información y Comunicaciones Avanzadas (ATICA 2018), 101-108, Universidad de Alcalá.
Ingavelez-Guerra, P., Hilera-González, J., Otón-Tortosa, S. (2018). Objetos de Aprendizaje Accesibles: Análisis desde sus metadatos y su relación con las normas ecuatorianas NTE ISO IEC 40500 y 24751. Ingeniería E Innovación, 6(2), 6. https://doi.org/10.21897/23460466.1718

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Ingavélez-Guerra, P., Otón-Tortosa, S., Teixeira, A., Robles-Bykbaev, V., Pérez-Muñoz, A. (2020). Exploring the Impact of Accessibility in MOOC and OER: A Multivocal Literature Review. European Distance and E-Learning Network Conference (EDEN 2020), , 95-104.
Oton, S., Ingavélez-Guerra, P. (2021). EduTech: Proposal for the Creation of Virtual Accessibility Assistance Units in Higher Education in Latin America. International Conference on Information Systems Development (ISD 2021).

Capítulos de Libros
Otón, S., Ingavélez-Guerra, P., Sánchez-Gordón, S., Sánchez-Gordón, M. (2020). Chapter 1. Evolution of accessibility metadata in educational resources. UXD and UCD Approaches for Accessible Education, 1-20. IGI Global.

Libros (como editora)
Pesántez, F., Sánchez, R., Robles, V., Ingavélez, P. (eds.) (2017). Inclusión, discapacidad y educación: enfoque práctico desde las tecnologías emergentes. Universidad Politécnica Salesiana.
Ingavélez, P., Hilera, J.R., Timbi, C., Bengochea, L. (eds). (2016). Tecnología y accesibilidad. Universidad de Alcalá.

Capítulo 4. Conclusiones y futuras líneas de investigación

4 Conclusiones y Futuras líneas de investigación

A través de los hallazgos, perspectivas de investigación y los desafíos planteados para mejorar el campo de la accesibilidad en la creación, gestión y evaluación de Objetos de Aprendizaje (OAs), resulta relevante explorar los esfuerzos generados por establecer modelos que fomenten la accesibilidad. La revisión sistemática de la literatura (SLR) del articulo 1 y 2 se relacionan con el campo de estudio (accesibilidad, adaptabilidad, metadatos, evaluación de e-learning). Las propuestas para transversalizar la accesibilidad en la educación virtual aún resulta complejo aplicarlas, esta problemática es reflejada en el articulo 3, donde se identifican modelos, estándares y buenas prácticas que buscan aportar en el proceso educativo virtual y el diseño del aprendizaje para todos.

Las ventajas de una adecuada implementación de la accesibilidad y adaptabilidad en OAs aún no es un conocimiento de dominio general. El artículo 4 establece una propuesta de solución enfocada en la correcta publicación de información de accesibilidad mediante metadatos, para favorecer la adopción de prácticas que generen una dirección futura que pueda centrarse en la efectiva búsqueda de recursos educativos que respondan a la necesidades y preferencias de un estudiante con discapacidad, considerando que los esfuerzos generados por crear material educativo accesible, enriquece la universalidad de la educación.

La creación, gestión y evaluación de OAs accesibles logran sincronía con recursos que pueden ser reutilizados. Sin duda, la educación genera material educativo valioso que podría favorecer repositorios y enriquecer el proceso educativo, que se fortalece en un entorno virtual al no conocer fronteras y tener una disponibilidad de compartir recursos digitales.

El análisis de casos en el artículo 4 nos ubica en el impacto de evaluar OAs accesibles a través de metadatos. Los hallazgos analizados manifiestan la potencialidad de su implementación. Se establece una necesidad importante en la generación de herramientas y técnicas que promuevan su desarrollo y fortalezcan su evaluación e impacto. Se considera que es necesario establecer directrices de accesibilidad que guíen en la eliminación de barreras, por lo que es necesario mantener una exploración e investigación activa de las fortalezas y debilidades de los recursos educativos accesibles, compatibilidad con tecnología de asistencia y la implementación y socialización de

herramientas que favorezcan las capacidades de evaluación de OAs accesibles para generar una cultura de diseño inclusivo, lo cual contribuye a una óptima evaluación de calidad. Se requiere de mayor investigación sobre las necesidades no solo de determinadas discapacidades, sino en el contexto de la experiencia del aprendizaje, competencias digitales, diseño de plataformas, mantenimiento e inclusión de nuevas características.

4.1 Aportaciones fundamentales de la tesis

El objetivo del presente documento es contribuir a establecer métricas evaluativas para la accesibilidad y adaptabilidad de OAs accesibles. Se considera también el empleo de una metodología rigurosa en el desarrollo de las diferentes publicaciones que ha generado esta tesis, con un óptimo nivel de fiabilidad afianzado en productos para el proyecto ERASMUS+ que sustenta la investigación realizada.

Se establece que hay una escasez de evaluación de accesibilidad en OAs a nivel general, y más aún avalado por personas con discapacidad. Además, los estudios disponibles tienden a centrarse más en las recomendaciones de diseño que en evaluar la efectividad de su implementación y proceso de mejora. El uso de estándares de accesibilidad es subjetivo, en varios casos responde a modelos evaluativos que, si bien consideran la accesibilidad como métrica, resulta inconsistente llegar a un proceso de implementación común, en especial con normativas de diversa interpretación en las legislaciones de cada país. Se carece de referencias que establezcan una muestra importante de estudiantes con discapacidad, su seguimiento, monitoreo y mejoramiento en el diseño del aprendizaje y competencias digitales, lo cual requiere un mayor tiempo para obtención de datos de confiabilidad.

Esta tesis se alimenta de los diversos modelos, estándares y herramientas empleadas para la aplicación de OAs accesibles, y propone la creación de herramientas que sustentan el modelo de accesibilidad y adaptabilidad considerando las necesidades y preferencias del estudiante, mediante la publicación de información de accesibilidad para una efectiva respuesta de búsqueda personalizada acorde a requerimientos de interacción de un recurso educativo, buscando una implementación idónea.

La información de estudios cuantitativos, cualitativos o mixtos enfocada hacia el impacto en estudiantes con discapacidad a nivel general, requiere de un proceso de auditoría y

mejoramiento continuo que involucre y comprometa a todos los actores dentro de un proyecto educativo que prevea además, competencias digitales que sustenten la efectividad de un modelo evaluativo de accesibilidad y adaptabilidad de un OA.

4.1.1 Modelo de evaluación de accesibilidad y adaptabilidad en recursos educativos

Los recursos educativos requieren ser vistos desde la necesidad de evaluar su calidad, centrada en las dimensiones propias de una formación educativa, su proceso y resultado. Establecer una evaluación de accesibilidad y adaptabilidad requiere dimensionar escenarios e interacciones del estudiante con un entorno virtual de aprendizaje y sus recursos, lo que conlleva buscar soluciones que respondan efectivamente a varias problemáticas. Las investigaciones y sus propuestas de modelos y técnicas convergen en puntos similares tales como: disminución de barreras (Mohamed & Yousef, 2014; Observatorio Accesibilidad TIC, 2013; Temesio & Motz, 2016), evaluación de calidad (Iniesto et al., 2017; Rodríguez et al., 2017) , retroalimentación de la experiencia del usuario (Iniesto & Rodrigo, s. f., 2016; Morales et al., 2016; Navarro et al., 2018; Open Education Consortium, 06:34:55 UTC), mejora en el diseño del aprendizaje (Gilligan et al., 2018; Iniesto & Rodrigo, s. f.), la personalización y recomendación (Fichten et al., 2014; Piedra et al., 2014; Salazar-Ospina et al., 2017; Teixeira et al., 2019), y la eficaz publicación de información de accesibilidad (Batanero et al., 2017; Ingavélez-Guerra et al., 2018) .

La socialización, sensibilización y el desarrollo de competencias digitales en todos los actores que aportan en la generación y consumo de recursos educativos accesibles, es un requisito indispensable para generar cultura de accesibilidad. La identificación de roles y responsabilidades convergen para la implementación sustentable en el tiempo de un modelo que apoye en la aplicación de la accesibilidad y adaptabilidad en OAs.

Para fomentar la evaluación de accesibilidad y adaptabilidad en OAs mediante un modelo, es necesario apalancarse en normativas y estándares que buscan garantizar la eficacia didáctica y tecnológica de recursos, lo que contribuye a procesos de calidad considerando a la accesibilidad como un parámetro evaluativo que sea sostenible en el tiempo e involucre a los tomadores de decisión en un proyecto educativo. La Figura 1 resume las áreas y procesos involucrados para lograr sinergias.

Figura 1: Componentes a considerar en un modelo de evaluación de accesibilidad y adaptabilidad en recursos educativos

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4.1.2 La propuesta de la herramienta

A nivel general, las investigaciones señalan la carencia de herramientas dominantes en la creación, gestión y evaluación de OAs accesibles y adaptables; con ello, las experiencias de educadores y estudiantes no reflejan un aporte significativo sobre análisis de acceso, evaluación y retroalimentación para mejorar un recurso accesible.

Es necesario respaldar la creación de herramientas automáticas que apoyen el uso de metadatos de accesibilidad, con análisis más robustos de acceso, interacción y retroalimentación de estudiantes con discapacidad para mejorar su implementación. La evidencia de modelos y metodologías que referencien directrices para el análisis de metadatos de accesibilidad, facilita la creación, gestión o adaptación de un OA, garantizando la eficacia didáctica y tecnológica dentro de un proceso evaluativo continuo. Además, la publicación eficiente de información de accesibilidad facilita una búsqueda óptima de recursos acorde a necesidades y preferencias del estudiante

Las herramientas generadas en esta investigación buscan lograr un tratamiento guiado en el uso de metadatos de accesibilidad avalado por estándares relacionados, para

generar un efecto multiplicador en desarrolladores de recursos educativos. El uso de metadatos de accesibilidad requiere ser extendido en recursos educativos accesibles, de tal manera que la curvatura de aprendizaje logre un lenguaje común con fácil implementación y retroalimentación de su importancia.

4.2 Revisión de los objetivos planteados

El planteamiento de esta tesis generó siete preguntas de investigación avaladas por los objetivos que se pretenden alcanzar. Con estos antecedentes, se presenta las respuestas a las preguntas y una tabla que sistematiza las relaciones encontradas con los capítulos de este documento.

RQ1: ¿Se emplean metadatos de accesibilidad en estándares y especificaciones sobre e-learning?

El empleo de metadatos de accesibilidad para modelos y estándares en entornos e-learning es sustentado en el capítulo 2. El estándar ISO 24751, y las especificaciones AfA, Schema, son analizados y constituyen la base para la propuesta del modelo de evaluación en DRD (Descripción de recursos digitales) en el capítulo 4. Si bien la accesibilidad en la Web está basada fundamentalmente en l recomendación WCAG, esta norma, no guarda en sí una correlación directa con la educación virtual, en virtud de que la complejidad de la educación involucra varias áreas que no solo enfoca a los recursos digitales, sino también a las características de aprendizaje del educando, como así lo señala el artículo 3 en la investigación de modelos evaluativos de e-learning. Con ello, la perspectiva del estudiante está directamente relacionada con su aprendizaje, y establece un análisis desde la adaptabilidad de un recurso en base a necesidades y preferencias personales (PNP). Con estos antecedentes se puede concluir que la respuesta a esta pregunta es afirmativa y está afianzada en dos publicaciones de alto impacto.

RQ2: ¿Es posible evaluar la accesibilidad y adaptabilidad en e-learning por la información contenida en metadatos?

El artículo 3 establece la situación problematizante al momento de evaluar la accesibilidad y adaptabilidad en e-learning y analiza una relación con la calidad y diversos modelos que buscan certificar procesos de mejora continua en la educación virtual. El uso adecuado de metadatos a nivel general y respondiendo a un idioma común, constituye una forma óptima de localizar recursos, consumirlos y socializarlos. El artículo 4 centra su propuesta en el uso de metadatos de accesibilidad para proponer un modelo de evaluación de accesibilidad y adaptabilidad, respetando las normativas iniciales de los OAs como son LOM y LRMI, pero fortaleciendo el uso estandarizado de metadatos de accesibilidad enfocado en los diversos esfuerzos de ISO 24751, AfA, Schema.org, WCAG y DUA. La propuesta del modelo se ve validada con los casos de estudio y las conclusiones obtenidas.

Como respuesta a esta pregunta se determina que sí es posible evaluar la accesibilidad y adaptabilidad en e-learning por la información contenida en sus metadatos. Sin embargo, la curvatura de aprendizaje guiada por la sensibilización para una cultura de inclusión educativa, aún está en proceso de desarrollo, pero su crecimiento en este periodo de pandemia es drástico, como lo avala el artículo 2, por lo que se espera llegar más pronto para medir los impactos de un aprendizaje para todos. De una u otra manera, la Educación para todos tiene sustento en varios temas (accesibilidad), pero un aprendizaje para todos (adaptabilidad) aún requiere medir esfuerzos y modelar conocimientos.

RQ3: ¿Podrían los metadatos de accesibilidad impactar positivamente en las preferencias y necesidades de un estudiante con discapacidad?

Si bien la accesibilidad se enfoca en generar escenarios posibilitantes de autonomía para todas las personas, en especial aquellas en situación de discapacidad, muchas veces la investigación tiende a establecer lineamientos que etiquetan determinadas discapacidades disminuyendo barreras para unos y aumentando para otros, y con ello la brecha digital no amenora, sino que se soslaya con justificaciones específicas centradas en la discapacidad. El artículo 3 plantea el problema de identificar las necesidades y preferencias del usuario desde su variabilidad en el aprendizaje y no desde la limitación de la discapacidad en si, por lo que el abanico de opciones se amplía por la diversidad humana que se pretende abarcar desde las necesidades y preferencias, que bien podrían ser similares a las de otro estudiante categorizado como “regular”. En este sentido, las mejores experiencias han sido dados por el modelo DUA (Diseño Universal del Aprendizaje) como respuesta a la diversidad y variabilidad en el aprendizaje, más que en etiquetar a una discapacidad en

particular. Este modelo es presentado en el artículo 4, donde el análisis de la adaptabilidad es identificado en las necesidades y preferencias basadas en las 3 redes de representación, expresión y motivación para su propuesta de categorización de metadatos.

Con estos antecedentes la respuesta a la pregunta planteada es que, sí es posible impactar positivamente en las necesidades y preferencias de todo estudiante mediante el uso adecuado de metadatos, en especial aquellos en situación de discapacidad. Es necesario considerar que la medición de impacto es un proceso de monitoreo y seguimiento continuo afianzado en el desarrollo sostenible de una cultura de inclusión educativa, basada en la sensibilización y conocimiento de potencialidades y no limitaciones.

RQ4: ¿Cómo se crean y gestionan recursos de aprendizaje accesibles a través de metadatos?

La utilización de metadatos en Objetos de Aprendizaje no constituye una práctica gratificante, por lo general está asociado a la plataforma o programa desarrollador que podrá el esfuerzo en aplicar los metadatos estándares, comunes o básicos de manera predeterminada. El artículo 1 y 3 señala los estándares frecuentemente empleados en OAs. Si los globales responden a un tratamiento automático, aun no se logra el uso generalizado de metadatos de accesibilidad, por lo que en el artículo 4 se plantean dos herramientas de etiquetado automático para evitar la dependencia de un conocimiento adicional para etiquetar adecuadamente un recurso, trasladando dicho esfuerzo a la herramienta y no al docente o al desarrollador y gestor de recursos educativos.

El artículo 4 y el desarrollo de las herramientas automáticas tales como OER-ADAPT y LOMPAD-WEB responde a esta pregunta, que está enfocada a cómo generar y gestionar OAs accesibles a través de metadatos, adicionando la transversalidad de un proceso de sensibilización y conocimiento sobre la diversidad y la necesidad de competencias digitales de los diferentes actores del proceso de enseñanza – aprendizaje.

RQ5: ¿Es posible establecer métricas acordes a metadatos de accesibilidad y adaptabilidad para evaluar un objeto de aprendizaje?

Si bien la revisión sistemática analizada en el artículo 1 y 2 destaca los modelos y estándares que están relacionados con metadatos de accesibilidad, la forma de aplicarlos aun es confusa, por lo que la necesidad de establecer métricas acorde a metadatos,

además de ser posible, es necesaria para lograr una evaluación que permita una mejora continua en la creación y gestión de OAs accesibles y adaptables. La propuesta de métricas se retroalimenta de evaluación de expertos en accesibilidad en el artículo 4.

En respuesta a esta pregunta se determina que sí es posible establecer métricas acordes a metadatos de accesibilidad y adaptabilidad para evaluar un objeto de aprendizaje, identificando características del recurso (DRD) en sus recursos digitales visuales, textuales, auditivos y su nivel de interactividad; así como también su impacto en el aprendizaje acorde a las necesidades y preferencias (PNP) establecidas en las redes de expresión, representación y motivación de DUA.

RQ6: ¿Es necesario proponer nuevos metadatos de accesibilidad y adaptabilidad para evaluar un objeto de aprendizaje acorde a uno o más modelos?

El análisis de uso de metadatos de accesibilidad en OAs aún es incipiente por cuanto no existe un acuerdo formal o normativas consensuadas para su adopción, en especial por modelos rectores como lo es LOM. El artículo 1 expone su poco uso y el artículo 3 la problemática que esto acarrea, por lo que es necesario usar herramientas de generación automática para una mayor experiencia con el uso de metadatos actuales, lo que permite una mejor investigación de requerimientos de nuevos metadatos de accesibilidad y adaptabilidad acorde a modelos.

Si bien en el artículo 4 se sugiere la creación de tres nuevos metadatos (uno de ellos es sustentado por la propuesta del Dr. Salvador Otón a Schema.org) y diez valores adicionales a metadatos existentes, para favorecer la validación de UDL, aún es necesario el empleo masificado de los metadatos actuales de accesibilidad.

La respuesta a esta pregunta, es parcialmente, pues aún es necesario el uso frecuente y socialización de los actuales metadatos de accesibilidad en plataformas y herramientas de creación de OAs, antes que proponer otros enfocados a modelos evaluativos específicos. Sin embargo, la base de conocimiento constituye un oportuno campo de aplicabilidad que responderá a la diversidad del aprendizaje posterior a una fase de implementación de herramientas y cultura evaluativa de accesibilidad en OAs.

RQ7: ¿Cuáles son los desafíos y oportunidades que se presentan en esta área de investigación?

Varios desafíos establecidos en el artículo 1 y 2 fueron detectados y abordados en la presente tesis al desarrollar herramientas que faciliten el adecuado proceso de etiquetado en OAs accesibles. De igual manera, las sugerencias de aplicación de estándares de uso general como lo es WCAG, y el desarrollo de mecanismos de evaluación son tratados en el artículo 4. El artículo 3 señala la problemática detectada en la implementación de metadatos de accesibilidad en OAs. Por otra parte, hay que destacar que los Objetivos de desarrollo sostenible de la UNESCO para el 2030 (UNESCO, 2015), establecen en su ODS 10 la reducción de las desigualdades, en ODS 4 la educación de calidad y en ODS 17 Alianzas para lograr los objetivos. Con estos antecedentes se considera como respuesta a esta pregunta la formalización de redes para potencializar las investigaciones realizada como soluciones a nivel nacional, regional y latinoamericano, con sinergias de experiencias europeas como los proyectos ESVIAL y Edutech de ERASMUS+, y planes de sostenibilidad que favorecen la aplicabilidad de presentes y futuras investigaciones, para determinar acciones conjuntas de socialización entre los socios latinoamericanos miembros del proyecto y posterior difusión en redes de investigación asociadas con la temática.

4.3 Futuras líneas de investigación

Las políticas internacionales, regulaciones legales y organizativas (Kurelovic, 2015) deben ser tomadas en cuenta para el análisis y gestión de involucrados (Ossiannilsson, 2019; Rodriguez-Ascaso et al., 2017; Temesio & Motz, 2016) El amplio abanico de tipos de discapacidad, la variabilidad en el aprendizaje y sus modos de interacción (Temesio & Motz, 2016) sugieren realizar análisis más profundos de la gran variedad de tecnología de asistencia y sus problemas técnicos (Batanero et al., 2017; Observatorio Accesibilidad TIC, 2013), retroalimentados por la experiencia del usuario, desarrollando un enfoque holístico (Iniesto & Rodrigo, 2016), entendiendo los desafíos pedagógicos y tecnológicos para lograr una reconstrucción mejorada con calidad (Atiaja & Proenza, 2016; Mohamed & Yousef, 2014; Rohs & Ganz, 2015). Es necesario evidenciar métricas definidas que avalen metodologías (Amado-Salvatierra et al., 2018) y referencien directrices o instrucciones internacionales relacionadas con el diseño para todos (Morales Martín, 2018). Todo proceso evaluativo de accesibilidad y adaptabilidad debe evidenciar la participación activa de personas en situación de discapacidad como sujetos activos de la investigación dentro de un proceso de co-diseño y co-evaluación continuo.

Es necesario elaborar e implementar regulaciones legales, especialmente en los países en desarrollo. La importancia de demostrar los beneficios de una educación para todos desde la implementación de OAs accesibles contribuye a una óptima evaluación de la calidad. Se requiere de mayor investigación en las necesidades, no solo de determinadas discapacidades, sino en el contexto de la experiencia del aprendizaje, diseño de plataformas, mantenimiento e inclusión de nuevas características.

La investigación en esta línea nunca tendrá fin, y los modelos evaluativos en e-learning requieren de actualización constante, por lo que se considera algunas líneas de investigación que podrían continuar con el estudio presentado hasta el momento.

4.3.1 Generación de un framework de inclusión educativa que alimente el modelado de conocimiento desde la diversidad en el aprendizaje

La constante evaluación y mejora de la accesibilidad en la educación virtual depende de la identificación de necesidades, por lo que un marco de trabajo (framework) puede dotar de recomendaciones y retroalimentarse de experiencias mediante técnicas de machine learning. Es necesario identificar estrategias mediante descripción de actividades e identificación de necesidades de accesibilidad en recursos educativos. El análisis de contenido e identificación de estrategias transversales puede alimentar casos que permitan un flujo combinado para lograr una gestión de cambio.

4.3.2 Análisis de competencias digitales- alfabetización digital de personas en situación de discapacidad

El informe de tecnología y discapacidad (ADECCO, 2022) señala que la pandemia generó un proceso drástico en uso de tecnología en todos los aspectos, viabilizando oportunidades para inclusión laboral y educativa; sin embargo, los avances tecnológicos deben ir acompañados de procesos de sensibilización en pro de una cultura de inclusión que elimine prejuicios, indiferencia, desconocimiento y discriminación, fortaleciendo la adquisición de competencias digitales de las personas en situación de discapacidad, en virtud de que los avances tecnológicos y sus herramientas, siempre estarán detrás de las personas y no implican un cambio de mentalidad social. Es importante considerar que el uso de adaptaciones tecnológicas, en muchos casos, permite eliminar barreras y lograr culminar estudios en igualdad de condiciones. El uso de recursos y aplicaciones

tecnológicas que faciliten la comprensión y su interacción fortalece el proceso de codiseño y coevaluación en entornos educativos. Sin embargo, es importante considerar que las adquisiciones de nueva tecnología podrían resultar costosas, por lo que es importante fortalecer la investigación en el desarrollo de hardware y software libre.

4.3.3 Análisis de escenarios virtuales y agentes inteligentes

La incorporación de sistemas inteligentes podría aportar en la evaluación de recursos accesibles y en la retroalimentación de perfiles y personalización desde la experiencia de usuario (Cedefop, 2016; Ingavélez-Guerra et al., 2018). Sin embargo, las posibilidades de análisis de escenarios de aprendizaje son diversas, sobre todo en el ámbito de la inclusión, que en muchos casos evalúa las competencias profesionales y habilidades. La implementación de agentes inteligentes podría generar percepciones que retroalimenten el sistema y proporcione múltiples alternativas como estrategias didácticas en el aprendizaje para todos.

Conclusions and future lines of research

4 Conclusions and future lines of research

Through the findings, research perspectives and the challenges posed to improve the field of accessibility in the creation, management and evaluation of Learning Objects (LOs), it is relevant to explore the efforts generated to establish models that promote accessibility. The systematic literature review (SLR) of articles 1 and 2 are related to the field of study (accessibility, adaptability, metadata, e-learning evaluation). The proposals for mainstreaming accessibility in virtual education are still complex to apply; this problem is reflected in article 3, where models, standards and good practices that seek to contribute to the virtual educational process and the design of learning for all are identified.

The advantages of a proper implementation of accessibility and adaptability in LOs is not yet a general knowledge. Article 4 establishes a proposed solution focused on the correct publication of accessibility information through metadata, to favor the adoption of practices that generate a future direction that can focus on the effective search for educational resources that respond to the needs and preferences of a student with a disability, considering that the efforts generated to create accessible educational material, enriches the universality of education.

The creation, management and evaluation of accessible LOs achieve synchrony with resources that can be reused. Undoubtedly, education generates valuable educational material that could favor repositories and enrich the educational process, which is strengthened in a virtual environment by not knowing borders and having the availability of sharing digital resources.

The analysis of cases in article 4 places us in the impact of evaluating accessible LOs through metadata. The findings analyzed show the potential of its implementation. An important need is established in the generation of tools and techniques that promote its development and strengthen its evaluation and impact. It is considered necessary to establish accessibility guidelines to guide in the elimination of barriers, so it is required to maintain an active exploration and research on the strengths and weaknesses of accessible educational resources, compatibility with assistive technology and the implementation and socialization of tools that favor the evaluation of accessible LOs to generate a culture of inclusive design, which contributes to an optimal quality evaluation. More research is required on the needs not only of specific disabilities, but in the context

of the learning experience, digital competencies, platform design, maintenance and inclusion of new features.

4.1 Fundamental contributions of the thesis

The objective of this document is to contribute to establish evaluation metrics for the accessibility and adaptability of LOs. It is also considered the use of a rigorous methodology in the development of the different publications that this thesis has generated, with an optimal level of reliability consolidated in products for the ERASMUS+ project that supports the research carried out.

It is established that there is a scarcity of accessibility evaluation in LOs at a general level, and even more so endorsed by people with disabilities. Moreover, the available studies tend to focus more on design recommendations than on evaluating the effectiveness of their implementation and improvement process. The use of accessibility standards is subjective, in several cases it responds to evaluative models that, although they consider accessibility as a metric, it is inconsistent to reach a common implementation process, especially with regulations of different interpretation in the legislations of each country. There is a lack of references that establish an important sample of students with disabilities, their follow-up, monitoring and improvement in learning design and digital competencies, which requires more time to obtain reliable data.

This thesis draws on the various models, standards and tools used for the implementation of accessible LOs, and proposes the creation of tools that support the model of accessibility and adaptability considering the needs and preferences of the student, through the publication of accessibility information for an effective personalized search response according to interaction requirements of an educational resource, looking for an ideal implementation.

The information from quantitative, qualitative or mixed studies focused on the impact on students with disabilities at a general level, requires an audit and continuous improvement process that involves and commits all stakeholders within an educational project that also provides for digital competencies that support the effectiveness of an evaluative model of accessibility and adaptability of an LO.

4.1.1 Evaluation model for accessibility and adaptability of educational resources

Educational resources require to be seen from the need to evaluate their quality, focused on the dimensions of an educational training, its process and result. Establishing an evaluation of accessibility and adaptability demands sizing scenarios and interactions of the student with a virtual learning environment and its resources, which entails searching for solutions that effectively respond to several problems. Researches and their proposed models and techniques converge on similar points such as: lowering barriers (Mohamed & Yousef, 2014; Observatorio Accesibilidad TIC, 2013; Temesio & Motz, 2016), quality assessment (Iniesto et al., 2017; Rodríguez et al., 2017), feedback of user experience (Iniesto & Rodrigo, s. f., 2016; Morales et al., 2016; Navarro et al., 2018; Open Education Consortium, 06:34:55 UTC), improved learning design (Gilligan et al., 2018; Iniesto & Rodrigo, s. f.), personalization and recommendation (Fichten et al., 2014; Piedra et al., 2014; Salazar-Ospina et al., 2017; Teixeira et al., 2019), and effective publication of accessibility information (Batanero et al., 2017; Ingavélez-Guerra et al., 2018) .

The socialization, awareness and development of digital competencies in all actors that contribute to the generation and consumption of accessible educational resources is an indispensable requirement to generate an accessibility culture. The identification of roles and responsibilities converge for the sustainable implementation over time of a model that supports the application of accessibility and adaptability in LOs.

To promote the evaluation of accessibility and adaptability in LOs through a model, it is necessary to leverage on regulations and standards that seek to ensure the didactic and technological effectiveness of resources, which contributes to quality processes considering accessibility as an evaluative parameter that is sustainable over time and involves decision makers in an educational project. Figura 1 summarizes the areas and processes involved to achieve synergies.

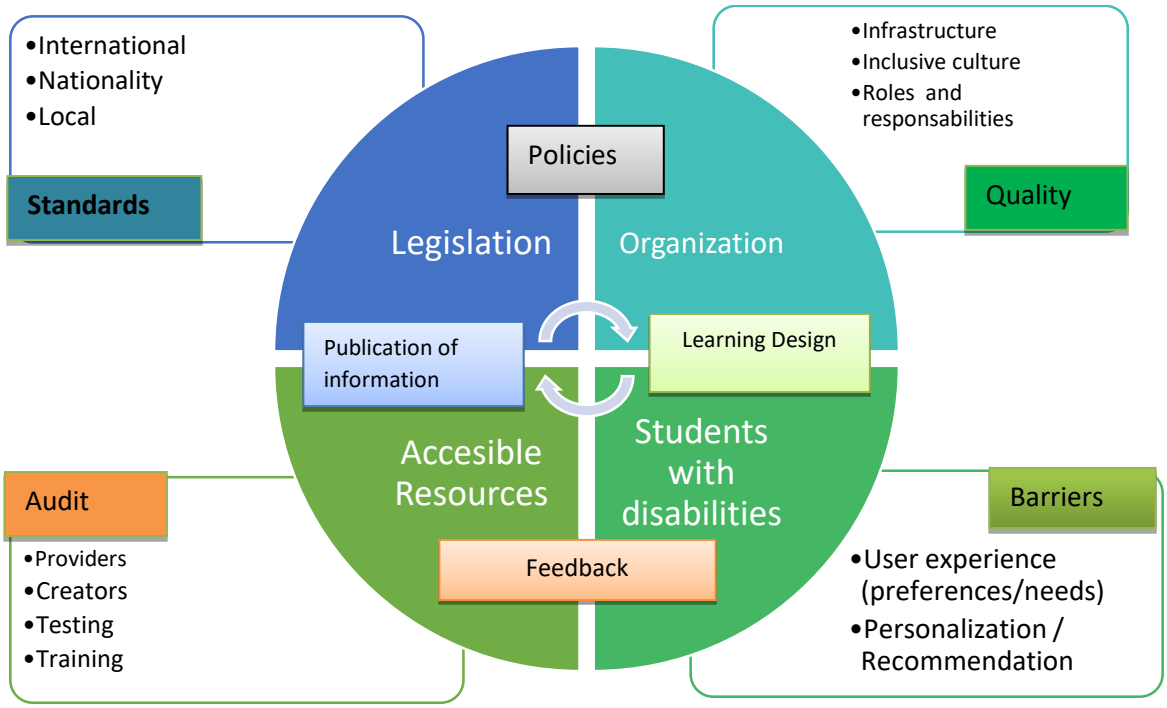

Figure 2: Components to consider in an accessibility and adaptability evaluation model for educational resources.

4.1.2 The proposal of the tool

At a general level, research reports a lack of dominant tools in the creation, management and evaluation of accessible and adaptive LOs; thus, the experiences of educators and students do not reflect a significant contribution on access analysis, evaluation and feedback to improve an accessible resource.

There is a need to support the creation of automated tools that support the use of accessibility metadata, with more robust analysis of access, interaction, and feedback from students with disabilities to improve implementation. The evidence of models and methodologies that reference guidelines for accessibility metadata analysis facilitates the creation, management or adaptation of an LO, guaranteeing didactic and technological effectiveness within a continuous evaluative process. In addition, the efficient publication of accessibility information facilitates an optimal search for resources according to student needs and preferences.

The tools generated in this research seek to achieve a guided treatment in the use of accessibility metadata supported by related standards, to generate a multiplier effect on

developers of educational resources. The use of accessibility metadata needs to be extended in accessible educational resources, so that the learning curve achieves a common language with easy implementation and feedback of its importance.

4.2 Review of the stated objectives

The approach of this thesis generated seven research questions supported by the objectives to be achieved. With this background, the answers to the questions and a table that systematizes the relationships found with the chapters of this document are presented.

RQ1: Is accessibility metadata used in e-learning standards and specifications?

The use of accessibility metadata for models and standards in e-learning environments is supported in chapter 2. The ISO 24751 standard, and the AfA, Schema specifications, are analyzed and constitute the basis for the evaluation model proposal in DRD (Digital Resource Description) in chapter 4. Although Web accessibility is mainly based on the WCAG recommendation, this standard does not have a direct correlation with virtual education, since the complexity of education involves several areas that not only focus on digital resources, but also on the learner's learning characteristics, as pointed out in article 3 in the research on evaluative models of e-learning. With this, the student's perspective is directly related to their learning, and establishes an analysis from the adaptability of a resource based on personal needs and preferences (PNP). With this background, it can be concluded that the answer to this question is affirmative and is supported by two high impact publications.

RQ2: Is it possible to evaluate accessibility and adaptability in e-learning by the information contained in metadata?

Article 3 establishes the problematic situation when evaluating accessibility and adaptability in e-learning and analyzes a relationship with quality and various models that seek to certify continuous improvement processes in virtual education. The appropriate use of metadata at a general level and responding to a common language, constitutes an optimal way of locating, consuming and socializing resources. Article 4 focuses its proposal on the use of accessibility metadata to propose an accessibility and adaptability evaluation model, respecting the initial standards of LOs such as LOM and LRMI, but strengthening the

standardized use of accessibility metadata focused on the various efforts of ISO 24751, AfA, Schema.org, WCAG and DUA. The model proposal is validated with the case studies and conclusions obtained.

As an answer to this question, it is possible to evaluate accessibility and adaptability in e-learning by the information contained in its metadata. However, the curvature of learning guided by awareness for a culture of educational inclusion is still in the process of development, but its growth in this period of pandemic is drastic, as supported by article 2, so it is expected to arrive sooner to measure the impacts of learning for all. In one way or another, Education for All is supported by several issues (accessibility), but learning for all (adaptability) still requires measuring efforts and modeling knowledge.

RQ3: Could accessibility metadata positively impact the preferences and needs of a student with a disability?

Although accessibility focuses on generating scenarios that enable autonomy for all people, especially those with disabilities, research often tends to establish guidelines that label certain disabilities, reducing barriers for some and increasing them for others, and thus the digital divide does not diminish, but rather is avoided with specific justifications focused on disability. Article 3 raises the problem of identifying the needs and preferences of the user from their variability in learning and not from the limitation of the disability itself, so the range of options is expanded by the human diversity that is intended to cover from the needs and preferences, which could well be similar to those of another student categorized as "regular". In this sense, the best experiences have been given by the UDL model (Universal Design for Learning) as a response to diversity and variability in learning, rather than labeling a particular disability. This model is presented in article 4, where the analysis of adaptability is identified in the needs and preferences based on the 3 networks of representation, expression and motivation for its proposed categorization of metadata.

With this background, the answer to the question posed is that it is possible to positively impact the needs and preferences of all students through the appropriate use of metadata, especially those with disabilities. It is necessary to consider that impact measurement is a process of continuous monitoring and follow-up based on the sustainable development of a culture of educational inclusion, based on awareness and knowledge of potentialities and not limitations.

RQ4: How do you create and manage learning resources accessible through metadata?

The use of metadata in Learning Objects is not a rewarding practice, it is usually associated with the platform or developer program that may make the effort to apply standard, common or basic metadata by default. Articles 1 and 3 point out the standards frequently used in LOs. If the global ones respond to an automatic treatment, the generalized use of accessibility metadata is not yet achieved, so article 4 proposes two automatic labeling tools to avoid the dependence on additional knowledge to properly label a resource, transferring this effort to the tool and not to the teacher or the developer and manager of educational resources.

Article 4 and the development of automatic tools such as OER-ADAPT and LOMPAD-WEB answer this question, which is focused on how to generate and manage LOs accessible through metadata, adding the transversality of a process of awareness and knowledge about diversity and the need for digital competencies of the different actors in the teaching-learning process.

RQ5: Is it possible to establish metrics according to accessibility and adaptability metadata to evaluate a learning object?

Although the systematic review analyzed in articles 1 and 2 highlights the models and standards that are related to accessibility metadata, the way to apply them is still unclear, so the need to establish metrics according to metadata, besides being possible, is necessary to achieve an evaluation that allows continuous improvement in the creation and management of accessible and adaptable LOs. The metrics proposal is fed by the evaluation of accessibility experts in article 4.

In response to this question, it is possible to establish metrics according to metadata of accessibility and adaptability to evaluate a learning object, identifying characteristics of the resource (DRD) in its visual, textual, auditory digital resources and its level of interactivity; as well as its impact on learning according to the needs and preferences (PNP) established in the networks of expression, representation and motivation of DUA.

RQ6: Is it necessary to propose new accessibility and adaptability metadata to evaluate a learning object according to one or more models?

The analysis of the use of accessibility metadata in LOs is still incipient because there is no formal agreement or consensus standards for its adoption, especially by guiding models such as LOM. Article 1 exposes its little use and article 3 the problems that this entails, so it is necessary to use automatic generation tools for a greater experience with the use of current metadata, which allows a better investigation of the requirements of new accessibility metadata and adaptability according to models.

Although article 4 suggests the creation of three new metadata (one of them is supported by Dr. Salvador Otón's proposal to Schema.org) and ten additional values to existing metadata, in order to favor the validation of UDL, it is still necessary the massive use of the current accessibility metadata.

The answer to this question is partially, because it is still necessary the frequent use and socialization of the current accessibility metadata in platforms and LO creation tools, before proposing others focused on specific evaluative models. However, the knowledge base constitutes a timely field of applicability that will respond to the diversity of learning after a phase of implementation of tools and evaluative culture of accessibility in LOs.

RQ7: What are the challenges and opportunities in this area of research?

Several challenges established in articles 1 and 2 were detected and addressed in this thesis by developing tools to facilitate the proper labeling process in accessible LOs. Similarly, suggestions for the application of general use standards such as WCAG, and the development of evaluation mechanisms are addressed in article 4. Article 3 points out the problems detected in the implementation of accessibility metadata in LOs. On the other hand, it should be noted that the Sustainable Development Goals of UNESCO for 2030 (UNESCO, 2015), establish in its SDG 10 the reduction of inequalities, in SDG 4 quality education and in SDG 17 partnerships to achieve the goals. With this background, it is considered as an answer to this question the formalization of networks to enhance the research carried out as solutions at national, regional and Latin American level, with synergies of European experiences such as the ESVIAL and Edutech projects of ERASMUS+, and sustainability plans that favor the applicability of present and future research, to determine joint actions of socialization between Latin American partners members of the project and subsequent dissemination in research networks associated with the subject.

4.3 Future lines of research

International policies, legal and organizational regulations (Kurelovic, 2015) should be taken into account for the analysis and management of involved (Ossiannilsson, 2019; Rodriguez-Ascaso et al., 2017; Temesio & Motz, 2016). The wide range of disability types, the variability in learning and their modes of interaction (Temesio & Motz, 2016) suggest performing deeper analyses of the wide variety of assistive technology and its technical problems (Batanero et al..., 2017; Observatorio Accesibilidad TIC, 2013), fed back by the user experience, developing a holistic approach (Iniesto & Rodrigo, 2016), understanding the pedagogical and technological challenges to achieve quality-enhanced reconstruction (Atiaja & Proenza, 2016; Mohamed & Yousef, 2014; Rohs & Ganz, 2015). It is necessary to evidence defined metrics that endorse methodologies (Amado-Salvatierra et al., 2018) and reference international guidelines or instructions related to design for all (Morales Martín, 2018). Any evaluative process of accessibility and adaptability must evidence the active participation of people with disabilities as active subjects of the research within a process of co-design and continuous co-evaluation.

It is necessary to elaborate and implement legal regulations, especially in developing countries. The importance of demonstrating the benefits of education for all from the implementation of accessible LOs contributes to optimal quality assessment. More research is needed on the needs, not only of specific disabilities, but in the context of the learning experience, platform design, maintenance and inclusion of new features.

Research in this line will never end, and evaluative models in e-learning require constant updating, so we consider some lines of research that could continue with the study presented so far.

4.3.1 Generation of a framework of educational inclusion that feeds the modeling of knowledge from diversity in learning

The constant evaluation and improvement of accessibility in virtual education depends on the identification of needs, so a framework can provide recommendations and feedback of experiences through machine learning techniques. It is important to identify strategies by describing activities and identifying accessibility needs in educational resources. Content analysis and identification of cross-cutting strategies can feed cases that allow a combined flow to achieve change management.

4.3.2 Analysis of digital competencies - digital literacy of people with disabilities.

The report on technology and disability (ADECCO, 2022) highlights that the pandemic generated a drastic process in the use of technology in all aspects, enabling opportunities for labor and educational inclusion; however, technological advances must be accompanied by awareness processes for a culture of inclusion that eliminates prejudice, indifference, ignorance and discrimination, strengthening the acquisition of digital skills of people with disabilities, since technological advances and their tools will always be behind people and do not imply a change in social mentality. It is important to consider that the use of technological adaptations, in many cases, allows the elimination of barriers and the completion of studies under equal conditions. The use of technological resources and applications that facilitate understanding and interaction strengthens the process of co-design and co-evaluation in educational environments. However, it is important to consider that the acquisition of new technology could be costly, so it is important to strengthen research in the development of free hardware and software.

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